

Task 3

Land Retirement

Final Report

February 1999

Land Retirement Technical Committee

The San Joaquin Valley Drainage Implementation Program

and

The University of California Salinity/Drainage Program

DISCLAIMER

This report presents the results of a study conducted by an independent Technical Committee for the Federal-State Interagency San Joaquin Valley Drainage Implementation Program. The Technical Committee was formed by the University of California Salinity/Drainage Program. The purpose of the report is to provide the Drainage Program agencies with information for consideration in updating alternatives for agricultural drainage water management. Publication of any findings or recommendations in this report should not be construed as representing the concurrence of the Program agencies. Also, mention of trade names or commercial products does not constitute agency endorsement or recommendation.

The San Joaquin Valley Drainage Implementation Program was established in 1991 as a cooperative effort of the United States Bureau of Reclamation, United States Fish and Wildlife Service, United States Geological Survey, United States Department of Agriculture-Natural Resources Conservation Service, California Water Resources Control Board, California Department of Fish and Game, California Department of Food and Agriculture, and the California Department of Water Resources.

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The San Joaquin Valley Drainage Implementation Program

Land Retirement Technical Committee Final Report

February 10, 1999

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Land Retirement Technical Committee Report

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LAND RETIREMENT COMMITTEE REPORT

Scope of the Committee Report

Chapter I

The SJVDP estimated abandonment of up to 460,000 acres of lands due to drainage problems including soil degradation by salinization by the year 2040. The land retirement option for retirement of 75,000 acres of land by the year 2040 as presented by the SJVDP is intended to enable agricultural production to continue at present levels in the future by reducing amounts of “problem water” and “problem acreage”. Chapter I summarizes the purpose and goals of the SJVDP, the land retirement recommendation of the SJVDP, and the definition, strategy, concept, areas of concern, basis, criteria, and objectives of land retirement.

Chapter II

A chronology of the SJVDIP since adoption of the Proposed Action Plan on December 11, 1996 and subsequent steps leading to preparation of a series of reports including Technical Reports is given in Chapter II. The responsibilities of the Technical Committees and specific objectives to be fulfilled by the Technical Reports are listed. The Committee objectives and the scope of the report are also presented.

Chapter III

The CVPIA Land Retirement Program also is focused on minimizing drainage problems so that more land may continue to be used for agricultural purposes. Chapter III discusses the Central Valley Project Improvement Act (CVPIA) Land Retirement Program, the San Joaquin Valley Drainage Relief Act, the U.S. Department of Agriculture’s Conservation Reserve Program and the Wetland Reserve Program. An update is also given concerning the Environmental Assessment, the Finding of No Significant Impact for the Expanded Demonstration Project of the CVPIA Land Retirement Program including various cooperative agreements with Westlands Water District.

Chapter IV

Implementing the land retirement option as presented by the SJVDP and the CVPIA is not without some expense in converting lands to other uses and managing water, soil, land, and wildlife resources to minimize adverse effects and maximize beneficial effects. Chapter IV describes the potential

consequences of the implementation of land retirement upon the hydrologic system (Section A), upon the quality of land from a biologic perspective (Section B) and a pedologic perspective (Section C), and upon the economic system (Section D). The results described in this section are based on computer modeling studies. Studies of this type have inherent limitations based on modeling assumptions, availability of data for modeling verification, and the accuracy of model predictions of natural phenomena. For the modeling studies described in this report, little baseline data was available for model verification. Therefore, modeling results must be carefully reviewed and interpreted based on modeling assumptions. In the absence of retired land monitoring data, the results of the modeling studies provided the best framework for Committee deliberations on the environmental and economic consequences of implementation of land retirement programs.

Chapter V

The analysis by the Subcommittee contains limitations that have been listed, to some extent, in the introductions to the chapters themselves. The fact that the chapters remain independent at this point underscores the experimental nature of land retirement. Chapter V gives recommendations concerning the implementation of land retirement to help both sustain agriculture and reduce risk to the environment. To achieve this balance, specific research needs are identified.

Because the Subarea Reports contained few details on implementation of land retirement, the subcommittee could not assess in detail the specifics of Grassland, Westlands, Tulare, and Kern hydrologic systems that have been brought successfully under management control or the efficacy of other implemented management options that could be used in conjunction with land retirement (e.g., groundwater pumping) in each subarea.

I. INTRODUCTION

Purpose and Goals of the San Joaquin Valley Drainage Program

The San Joaquin Valley Drainage Program (SJVDP) from 1985 to 1990 was a dedicated effort to resolve the subsurface drainage water problem of the western San Joaquin Valley (SJV) (SJVDP, 1989 and 1990, see especially *Prefaces* to both volumes, pages iii, and iv in 1989 and pages iii and one in 1990). With implementation of the regional plan of specific management alternatives (SJVDP, 1990, Table 1), progress would be made both in managing and treating drainage-water toxicants associated with ecotoxicity within the valley and developing long-term solutions to address the elevated groundwater conditions and the annual salt build-up that eventually limit the uses of valley lands and groundwater. The strength of the SJVDP lies in its concerted, cooperative approach and its suggested framework of alternatives built on a regional perspective from documented studies. Benefits would occur during the 50-year program period as agricultural production continued at present levels (SJVDP, 1990, Table 46), without predicted abandonment of lands due to salinization (SJVDP, 1990, Tables 11 and 45), and as fish and wildlife resources were restored and protected from the adverse effects of selenium in receiving waters (SJVDP, 1990, Tables 41, 42, and 44). Monitoring, initially and continuing throughout the program period based on the developed regional framework, would add site-specific data and analysis necessary for evaluating the long-term success of the SJVDP.

The initial scientific documentation which provided the basis for the choice of management alternatives, including land retirement, was an important part of the SJVDP. An extensive library (e.g., SJVDP, 1989; SJVDP, 1990, pages 163-175) of supporting measurements, technical analysis, maps, and models exist to help quantify drainage conditions, understand drainage management, and assess the benefits from a regionally implemented plan. The initial assessment included a compilation of historical data, execution of baseline field studies for the period 1985 through 1988, and development of planning objectives, criteria, and performance standards based on water-quantity, water-quality (i.e., protection of aquatic life, wildlife, and public health) and land use (SJVDP, 1990, Tables 7, 15, 16). Some final documentation of field studies was published after the completion of the summary report of the SJVDP (e.g., for land retirement, see Belitz and Phillips, 1992; for Tulare Basin, see Fujii and Swain, 1995) and further technical analysis of the work of the program continues to be published (e.g., Dinar and Zilberman, 1991; and Frankenberger and Benson, 1994; Frankenberger and Engberg, 1998).

Land Retirement Recommendation of the San Joaquin Valley Drainage Program

Retirement of irrigated agricultural lands was a management component of the SJVDP to achieve load reduction, in general, of dissolved constituents and, in particular, of trace elements such as selenium, present in subsurface drainage generated from lands of the western valley. Characteristics to identify irrigated farmlands for selective land retirement were developed (e.g., a regional map showing selenium (Se) concentrations greater than 50 and 200 parts per billion (ppb) in shallow ground water, SJVDP, 1990, Figure 23). This allowed specific criteria to be applied to the identified subareas (i.e., Northern, Grassland, Wetlands, Tulare, and Kern) to estimate the number of acres applicable to land retirement, the amount of associated problem water reduction, and amount of water freed-up to restore and enhance drainage-contaminated habitat in the identified subareas (SJVDP, 1990, Tables 1, 2, 23, 24, 29, 32, 35, 38, 41, and 42).

The adverse effects, limitations, and benefits of each management option were evaluated by the SJVDP (SJVDP, 1990, Table 17). Potential negative effects listed for land retirement included loss of agricultural productivity, perhaps permanently, and loss of revenue to surrounding communities. Uncertainties included those associated with reuse of retired lands as wildlife habitat, with retired-land maintenance including dust control, with potential preservation of retired lands in reserve for future re-introduction to irrigated or dry-land agriculture, and with institutional changes concerning repayment of federal and state water contracts. Benefits would accrue from economic return to the landowner from the sale of property, the sale or lease of irrigation water supply, the reduced cost of handling drainage, and allocation of freed-up water to beneficial uses, and the reduced risk of selenium exposure to fish and wildlife.

Implementation of land retirement as envisioned by the SJVDP would concurrently reduce problem water and conserve or free-up good-quality water (SJVDP, 1990, Tables 22 and 24). Amounts of water needed for the protection and restoration of fish and wildlife resources also were identified by the SJVDP (SJVDP, 1990, Table 42). In general, the amount of problem water reduction (SJVDP, 1990, Table 2) compared to the amount of water potentially available through the recommended plan actions (SJVDP, 1990, Tables 41 and 44) give a measure of the overall impact of land retirement. For the recommended plan, the amount of water potentially made available (SJVDP, 1990, Table 41) divided by the amount of problem water reduced (SJVDP, 1990, Table 2) is the highest (3.6) for the land retirement option when compared to groundwater management (2.1) and source control (1.6) options. Comparisons among alternatives also were performed using other measures or criteria (e.g., the social cost of land retirement compared to the social cost of implementing alternative drainage management methods, Stroh, 1991).

The final recommended management plan for each subarea included

development of alternatives based on emphasizing: (1) conservation and reuse of agricultural water, (2) extraction of irrigation water from the semi-confined aquifer, and (3) retirement of irrigated agricultural lands overlying shallow ground water containing greatly elevated concentrations of dissolved selenium (SJVDP, page 98, Tables 18 through 22, and Figures 25, 26, and 27). One of the conclusions of the alternatives analysis used in the formulation of the final recommended plan concerning land retirement was that the land-retirement-component should be maximized if minimizing risk from toxicants was the dominant objective (SJVDP, 1990, page 118). Specifically, if lands overlying areas of shallow ground water with concentrations of selenium exceeding 200 ppb were retired as priority candidates, land retirement would achieve selenium load reduction as opposed to a management or redistribution of load on a temporal basis (e.g., reuse and source control). If conserving water at least-cost is the maximized objective, source control and reuse options should be pursued. However, formulation of the final recommended plan for land retirement by the SJVDP, as with the other components, was based on factors specific to the subareas and sites considered (e.g., ability to discharge to the San Joaquin River or closed basin), as well as an overall plan formulation (SJVDP, 1989; SJVDP, 1990, e.g., Figure 28, drainage reduction). The decision to retire lands made by the SJVDP did not preclude the future option of re-establishing irrigated agriculture if circumstances should change (SJVDP, 1990, page 121).

In the following section, excerpts from the SJVDP's final report (1990) give a summary of the land retirement management alternative as it was originally conceived. In the final section, details of the planned implementation of the regional land retirement alternative have been compiled and referenced. These details include the definition, basis, criteria, and specific objectives (e.g., applicable acreage, amount of problem water reduction) of the recommendation.

San Joaquin Valley Drainage Program Land Retirement Planning Alternatives

Drainage Management Strategies Underlying the (Planning) Alternatives Land Retirement (SJVDP, 1990 excerpts, page 103 and narratives of Figure 22 and 23):

Land Retirement:

The essential strategy of land retirement is to stop irrigating lands with poor drainage characteristics beneath which now lies shallow ground water so contaminated with selenium (and other substances) that drainage would be extremely difficult and the water produced would be costly to manage. Hydrologic investigations (Gilliom, et al., 1989) indicate that, if substantial land area (say +5,000 acres) were retired from irrigation, the shallow water table beneath those lands would drop. To some extent, instead of contributing to their

contamination, the dewatered area beneath the retired lands would then become a sink to receive some contaminated water from adjacent lands. Figure 22 illustrates how land retirement would lower groundwater levels.

The feasibility of this strategy hinges on the existence of shallow groundwater areas in which concentrations of selenium are much greater than those of surrounding areas. Figure 23 shows areas in which selenium concentrations in shallow ground water are more than 50 and 200 ppb. Areas over 200 ppb are considered to be “hot spots” and special candidates for retirement. The feasibility of land retirement also may depend on the existence of compensating benefits in the form of overall reduced costs of handling the drainage problem regionally, or in economic return to landowners from the sale or lease of the water supply no longer used for irrigation.

related aspect of land retirement is that it could be considered a land reserve and, if at some future time, the problem necessitating retirement were to be resolved, the land could be used again for irrigated agriculture.

THE CONCEPT OF LAND RETIREMENT (SJVDP, 1990, Figure 22)

CONDITION ONE

Continuing Irrigation of High Selenium Areas having Poor Drainage Characteristics

- *Crop roots water-logged and soils becoming saline.*
- *High concentration of selenium dissolved in the water render drainage and disposal difficult and costly*
- *Selenium and the other contaminants from this area contribute to the degradation of the regional aquifer.*

CONDITION TWO

Retire Land from Irrigation

- *Land retired from irrigated crops*
- *Water table has dropped 20 feet in 10-15 years*

- *Selenium and other contaminants do not contribute to the degradation of the regional aquifer*
- *Possibility that retired areas become a sink for the poor quality water in nearby shallow ground water*

Map of Areas of Highest Observed Selenium Concentrations In Shallow Ground Water (SJVDP, 1990, Figure 23)

- *exceeds 50 ppb Se*
- *exceeds 200 ppb Se*

San Joaquin Valley Drainage Program Land Retirement Definition, Basis, Criteria, and Objectives

Definition

Intentionally discontinuing irrigation of selected farmlands.

Basis

- Land retirement would remove from production those farmlands contributing the poorest quality subsurface drainage water, thereby reducing the volume of problem water by approximately 0.65 - 0.75 acre-feet/acre/year (ac-ft./ac/yr.) (SJVDP, 1990, Table 26), and improving the quality of drainage waters to be managed. Lands overlying areas of shallow ground water with concentrations of selenium exceeding 200 ppb Se are identified as those lands contributing the largest percentage of selenium to drainage discharge (SJVDP, 1990, Figure 23). The shallow groundwater table beneath retired farmlands is predicted to drop based on a regional assessment of implementation of retiring land of a substantial area (SJVDP, 1990, page 103; Belitz and Phillips, 1992; Swain, 1990).).
- Land retirement would free-up irrigation water (2.2 - 2.8 ac-ft./ac/yr., page 118) for potential reallocation to beneficial uses (e.g. wetlands, in-stream flows).
- Retired farmlands could potentially be managed as wildlife habitat although this type of land reuse is unproved in the SJV (SJVDP, 1990, Table 17). In order to ensure that habitat benefits were realized, it is likely that such retired lands would have to be managed as uplands. Surveys of the lands (Endangered Species Act consultation and NEPA compliance) would take place prior to selection and a comprehensive monitoring plan would be in place to determine the safety of these lands to wildlife and to document restoration changes. Restored terrestrial habitats could benefit a number of

species, including endangered and threatened plants and animals. Habitat benefits would be greater with larger block sizes (e.g., > 5,000 acres) in proximity to existing wildlife areas and other undeveloped lands, and as additional farmland retirements provided corridors. Intentional efforts to replant/reintroduce grasses, forbs, and shrubs would speed up habitat restoration and increase the presence of native plants. The addition of micro-relief to the landscape would benefit burrowing animals. (Moore et al., 1990; SJVDP, 1990; Swain, 1990).

Criteria

Recommended for retirement were irrigated farmlands with the following characteristics (SJVDP, page 103, Tables 7, 15,16, 23, and 24, and Figure 23):

- Large, contiguous blocks of farmland (> 5,000 acres);
- Farmlands with low agricultural productivity (USBR land classes 4 and 6, or Storie Index classes 4, 5, and 6);
- Farmlands with shallow groundwater table (≤ 5 or ≤ 10 feet below the surface);
- Farmlands with poor groundwater quality (≥ 50 ppb Se); and
- Lands overlying areas of shallow ground water with concentrations of selenium exceeding 200 ppb Se are special candidates for retirement.

Objectives

Applicable acreage (SJVDP, 1990, Tables 15 and 16)

- 55,100 acres (Level A, > 200 ppb Se)
- 263,900 acres (Level B, > 50 ppb Se) (see Footnote #1 concerning correction of SJVDP, 1990, Table 16)

Recommended Acreage (SJVDP, 1990, Tables 24, 29, 32, 35, 38)

- 21,000 acres (year 2000)
- 75,000 acres (year 2040)

Problem Water Reduction (SJVDP, 1990, Table 2, 29, 32, 35,38)

- 16,000 acre-feet/yr. (year 2000)

- 55,300 acre-feet/yr. (year 2040)

Freed-Up Water through Implementation of SJVDP Management Options (SJVDP, 1990, Table 41)

- 56,000 ac-ft./yr. (year 2000)
- 199,000 ac-ft./yr. (year 2040)

Reallocated Water Uses (SJVDP, 1990, Table 42)

Total of Annual Water Needs for Fish Protection, Substitute Water Supply for Wildlife Areas, and Alternative Habitat for Evaporation Ponds

- 167,400 ac-ft./yr. (2000)
- 193,900 ac-ft./yr. (2040)

Annualized Costs of the Recommended Plan over the 50-year program period (SJVDP, 1990, Table 3 and pages 5 and 118, and Table 17; the value of conserved water for other uses has not been included as a cost offset)

- Purchase of land/year \$2,818,000 (\$140,900,000 annualized over 50 year period at 10% interest; approximate cost per acre \$1,500-1,900)
- Operation, maintenance, or replacement/year \$300,000
- Annual costs/acre of land served, \$170

Footnote #1: The number of acres (453,900) reported for the extent of land considered for land retirement under Level B Performance Standards, from SJVDP, 1990, Table 16, page 94, is incorrect. The problem is a misprint for the number of acres for the Kern Subarea, Zone A (219.5 Ac. in the table, interpreted as 219.5k Ac.). The size of the entire Kern Zone A is less than 30,000 acres, and the area with selenium >50 ppb may be verified with the data on page 5-58 of the *Technical Information Record, Documentation of the Use of Data, Analysis, and Evaluation Processes that Resulted in the SJVDIP Recommended Plan* (SJVDP, September, 1990). The misprint for Kern Zone A should likely have read 29.5k Ac., yielding a total Level B acreage of 263,900, instead of 453,900 (personal communication, Wayne Verrill, 10/7/98)

II. TECHNICAL COMMITTEE OBJECTIVES

The following paragraphs are excerpts from the SJVDIP Activity Plan adopted by the SJVDIP Management Group on March 24, 1997.

“On December 11, 1996, the Management Group of the San Joaquin Valley Drainage Implementation Program approved, in concept, a “Proposed Action Plan,” advanced by an association of local districts, the University of California, and the California Department of Food and Agriculture, to update the Management Plan. This Activity Plan will be carried out in three stages.

The first stage in updating the Management Plan will consist of two concurrent, coordinated, and independent tasks. One task will be the preparation of reports on San Joaquin Valley drainage problem areas by Subarea Committees which will assess the progress toward, and constraints of, adopting management recommendations in the Management Plan. The second task will be current technical and economic evaluation of the management options proposed in the Management Plan and salt utilization by a set of technical committees.

The second stage will be synthesis of the information reported under activities of the first stage into a report which identifies interactions between management options, trade-offs between management options, and a set of recommendations based on technical and economic considerations. This task will be accomplished by an “Ad Hoc Coordination Committee.”

The third stage will use the recommendations formulated during the second stage along with input from the public sector to formulate an updated management plan and identify acceptable mechanisms conducive to adoption and voluntary implementation of the updated management plan.

Technical Committee Responsibilities

Technical Committees will conduct an assessment analysis of issues pertaining to drainage in the San Joaquin Valley. The analysis shall include technical and economic parameters. Individual Technical Committees will: (1) evaluate the subject areas of the major components of the Management Plan, together with salt utilization, on the basis of recent and current research and results of pilot projects, (2) review the Subarea reports, and (3) prepare reports for the Ad Hoc Coordination Committee. Institutional and fish and wildlife components of the Management Plan will be addressed by Technical Committees as appropriate. Technical Committees will list all options in each component area, conduct a technical and economic evaluation of all options that are ready for implementation, identify the feasible area of application along with limitations, and identify additional work needed on options. Committee reports will make a separate analysis for each Subarea as appropriate, identify tradeoffs associated with each alternative course of action, and identify areas needing

further study.”

The Land Retirement Technical Committee will carry out the responsibilities assigned to the technical committee on land retirement component of the Rainbow Report. Thus the committee will evaluate the land retirement component of the Rainbow Report on the basis of the recent and current research, pilot projects, and other recent actions including relevant information contained in the subarea reports submitted to the Committee. The committee’s specific objectives are to:

- Review the assumptions and criteria of the Rainbow Report;
- Present an overview of land retirement-related actions taken since publication of the Rainbow Report in 1990;
- Identify consequences (impacts on environment and economy) and benefits (contribution to selenium impact reduction) of Rainbow Report recommendation on land retirement;
- If necessary, make recommended changes to the Rainbow Report criteria, assumptions, and recommendation;
- Recommend how Rainbow Report land retirement may be implemented to reduce risk to the environment, provide safe habitat for wildlife, and sustain agricultural productivity; and

Identify research, evaluation and data needs.

III. RECENT ACTIONS/NEW INFORMATION/DEVELOPMENTS

Central Valley Project Improvement Act (CVPIA) Land Retirement Program

On October 30, 1992, Congress enacted the Central Valley Project Improvement Act (CVPIA, Public Law 102-575). Section 3408(h)(1), Title 34 of the CVPIA authorized a federal land retirement program, as recommended by the San Joaquin Valley Drainage Program Final Report (San Joaquin Valley Drainage Program 1990). The CVPIA modified the priorities of the Central Valley Project (CVP) and established aggressive goals for the restoration of the fish and wildlife in California’s Central Valley. The CVPIA provided the Secretary of the Interior with a number of authorities as tools to accomplish those goals. At the same time, the CVPIA recognized that additional management and measurement tools were needed and would be developed over time. Land retirement is one of the management tools authorized to assist in the achievement of CVPIA goals. Other options include improvements in or modifications of the operations of the CVP, water banking, conservation, transfers, and conjunctive use.

Section 3408(h)(1) of the CVPIA authorizes the purchase, from willing sellers, of land and associated water rights and other property interests which receives Central Valley Project water under a contract executed with the United States. Section 3408 (h) (2) of the CVPIA authorizes the Secretary of the Interior to purchase agricultural land which, in the opinion of the Secretary, (A) would, if permanently retired from irrigation, improve water conservation by a district, or improve the quality of an irrigation district's agricultural wastewater and assist the district in implementing the provisions of a water conservation plan approved under section 210 of the Reclamation Reform Act of 1982 and agricultural wastewater management activities developed pursuant to recommendations specific to water conservation, drainage source reduction, and land retirement contained in the final report of the San Joaquin Valley Drainage Program (1990); or (B) are no longer suitable for sustained agricultural production because of permanent damage resulting from severe drainage or agricultural wastewater management problems, groundwater withdrawals, or other causes.

The U.S. Bureau of Reclamation (Reclamation), in partnership with the U.S. Fish and Wildlife Service (USFWS) and the U.S. Bureau of Land Management (BLM) are the responsible Federal agencies for implementing the CVPIA Land Retirement Program. Representatives from each of these agencies make up the Inter-agency land retirement team and will work in partnership to accomplish the goals of the land retirement program. The program is expected to retire a total of about 100,000 acres of irrigated farmland. The actual amount of land retired and duration of the program will be dependent upon the number of willing sellers and budget constraints. All land considered for retirement must come from willing sellers. Reclamation will not use condemnation to acquire land or other property interests. The USFWS and the BLM will act as land managers for lands acquired under the CVPIA Land Retirement Program.

All lands that receive Central Valley Project (CVP) water are eligible for participation in the land retirement program. However, it is anticipated that all lands selected for retirement will be located south of the Sacramento-San Joaquin Delta where drainage and water quality are poor. This area was identified as the project area for the San Joaquin Valley Drainage Program Final Report (San Joaquin Valley Drainage Program 1990). There are approximately 1.8 million acres of irrigated farmland located south of the Sacramento-San Joaquin Delta that receive CVP water. Many of these lands have elevated concentrations of selenium in the soils and shallow ground water. Elevated levels of salinity, boron, molybdenum, and arsenic also are present on many lands.

In 1994, Reclamation and DWR conducted several public workshops in the Central Valley, Sacramento, and San Francisco Bay Area. Those workshops explored the level of interest and concerns among landowners, environmental interests, local water suppliers, and drainage interests. Reclamation then

developed Draft Interim Procedures and Guidelines in consultation with DWR and finally published interim guidelines (see Appendix A) after much consultation with various agencies, interested organizations, and members of the public (U.S. Department of the Interior 1997). The guidelines address procedures for soliciting lands eligible for retirement; a process for selecting lands for retirement (criteria); the role of local water districts in setting priorities for retirement; interests that might be acquired; and post-retirement management of land and water resources. It is anticipated that the guidelines will be further refined (hence the term “interim”) based on information generated through the Land Retirement Demonstration Project. The demonstration project was the subject of a recent Environmental Assessment and Finding of No Significant Impact and involves retiring a parcel of land within the Westlands Water District and developing habitat enhancement strategies to test through an adaptive management approach. The Interagency Land Retirement Team expects to develop a monitoring plan and adaptive management strategy for the demonstration project and use the parcel to refine strategies to land and water management within the context of land retirement.

The land retirement program is based on an eight-step process-solicitation of offers; submission of applications by willing sellers; review of applications; selection of parcels for retirement; appraisal of the property value; preparation of land use and water management plans; site-specific environmental impact analysis of parcel retirement; retirement of land; and implementation of management plans.

The ranking criteria includes depth to groundwater, selenium concentration in groundwater, salinity of groundwater, boron concentration in groundwater, soil drainage classification, risk of exposure to contaminated water, (This ranking criteria considers if the parcel to be purchased has active drainage to the SJR or a pond and/or if the parcel has potential to drain to the SJR or a pond.), parcel location, potential to restore habitat, parcel size, and amount of water available. Through these criteria, lands that have drainage and groundwater quality problems would be selected and retired from agricultural production. Given that another purpose of the program is to improve fish and wildlife habitat, large blocks of land with drainage and groundwater quality problems located next to other retirement lands or existing wildlife habitat will be given higher priority.

The following research activities are being funded by the CVPIA Land Retirement Program:

2-Dimensional Ground Flow Model in the Panoche Water District, 1997, Purkey, D.R. and Wallender, W.W., U.C. Davis. Model simulates the hydrologic impacts of land retirement at the local farm field scale. (This project has been completed and is summarized in section D1.)

Update of the U.S.G.S. Ground Water Flow Model for the Western San Joaquin Valley. In progress by J. Fio, Hydrofocus Inc. Model will be used to simulate the hydrologic impacts of land retirement at the regional scale.

Contributed funding for the UC Davis Study entitled, Water and Land Management in Irrigated Ecosystems, Wallender, W.W. and others. In progress. An agricultural-economic model to quantify the economic, environmental and social impacts of reductions in surface water supplies, and reductions in lands irrigated in the vicinity of Firebaugh.

Land Retirement Demonstration Project, Endangered Species Recovery Program. In progress. Provides funding for the study of revegetation, habitat restoration, and monitoring of retired demonstration project lands.

State Land Retirement Program

Concurrent with passage of the federal CVPIA, the California legislature passed Senate Bill (SB) 1669, the San Joaquin Valley Drainage Relief Act, in 1992. This bill incorporated recommendations of the San Joaquin Valley Drainage Program, including the authorization of a state land retirement program (California Water Code, Section 14900) to be administered through the California Department of Water Resources (DWR). The state land retirement program is not currently funded; however, the federal government is moving forward with the CVPIA Title 34 requirements and the federal environmental review process.

Other Land Retirement Programs

The largest land retirement program in the country is the Conservation Reserve Program (CRP). Originally authorized in the Food Security Act of 1985, the CRP is administered by the U.S. Department of Agriculture (USDA) with a goal of reducing soil erosion from highly erodible crop lands. The CRP is a medium-term program in which farmers submit bids representing their willingness to accept payment to remove their land from agricultural production. By 1989 the USDA had enrolled 33.9 million acres of cropland into the CRP. In contrast to the land retirement program envisioned for the drainage problem area, which covers a longer time horizon, winning CRP bids retire land for a 10 year period and landowners retain title to the parcel and are free to resume crop production upon contract expiration.

CRP focus appears to have been on the quantity of land enrolled, rather than on the environmental benefits of enrolling land (Wu and Babcock, 1996). Beginning in 1987, water quality objectives took increasing prominence in CRP design, with filter strips, cropped wetlands, and lands subject to scour erosion gaining eligibility (Osborn et al., 1995). In particular, those parcels that are both highly erodible and adjacent to an impacted water way would receive higher priority for entry into the program than, for example a similar parcel that either is

less erodible (e.g., is not steeply sloped) or is farther from the water course. Although originally established to address soil erosion problems, this program has been gaining attention recently for its potential to provide environmental services, such as wildlife habitat (e.g., Szentandrasi, et al., 1995). More recent rounds of the CRP have attempted to incorporate environmental objectives by enrolling only environmentally sensitive lands (Wu and Babcock, 1996). About 2.5 million additional acres were enrolled under these new rules.

Prominent among other land retirement programs is the Wetlands Reserve Program (WRP), administered by the USDA in a similar fashion to the CRP, but with an objective of preserving the nation's wetlands. Farmers participating in the WRP sell long-term production easements to the government. Interior's Bureau of Reclamation may implement a program to retire agricultural lands in the Colorado River Basin to help reduce salt loading, and enhance fish habitat, in that river (Ekstrand and Johnson, 1995).

CVPIA Land Retirement Demonstration Project and the Donohoe Pilot Project

The USBR at this writing is preparing environmental documentation on the CVPIA Land Retirement Program that includes an expanded Demonstration Project up to 15,000 acres. The expanded project is in response to comments received during public meetings on the Land Retirement Demonstration Project Draft EA. Concerns were expressed that the planned 1,891 acre Demonstration Project would be too small to support statistically credible analyses, would not demonstrate the resulting effects on upslope versus downslope groundwater movements, and would not assess varying impacts of retiring lands with different drainage characteristics. In addition, an expanded Demonstration Project would be needed to confirm the accuracy of the fundamental assumptions of the program, such as reductions in drainage-related impacts, before implementing large-scale land retirement of up to 100,000 acres.

In response to these comments, the USBR has expanded the Land Retirement Demonstration Project from 1,891 acres to 15,000 acres. The additional acreage will come from the voluntary sale of drainage impacted lands meeting USBR criteria within western Fresno County, southeastern Kings County, and southwestern Tulare County. The expanded project will include the 1,891 acres previously identified, and will expand with as yet unspecified lands from the Westlands subarea to include land with different soil, water, and drainage characteristics in the Tulare subarea. The specific purpose of the Demonstration Project is to determine if the current criteria for selection of lands in the Land Retirement Program Interim Guidelines are adequate to accomplish the mission of the Program to reduce drainage, improve water quality in the San Joaquin River, establish wildlife habitat, and determine which restoration techniques and land management options will work best under various scenarios.

The USBR has negotiated a cooperative agreement with Westlands Water District regarding lands retired within WWD. Some of the terms of the cooperative agreement are:

1. The first 15,000 acres of lands in the District lands that are retired are to be retired pursuant to the agreement;
2. The amount paid by Interior for the purchase of retired land shall be the value of the land absent any appreciation due to the availability of Project water; the District will pay the difference between that value and the full fair market value of the land up to \$1,150 per acre;
3. The District will be permitted to reallocate the CVP water to which the retired lands are entitled to other lands in the District, provided that they do not lie within the designated drainage-impacted region of the District;
4. Interior may apply for an allocation from the District supplemental water supply for the purpose of establishing vegetation on retired lands for upland habitat.

The Expanded Land Retirement Demonstration Project Environmental Assessment (EA) is currently being revised in response to comments received from interested stakeholders. The EA will include analysis of alternatives not considered in the original document regarding disposition of water. The cooperative agreement with WWD has been suspended until the environmental impacts associated with the agreement can be analyzed and publicly disclosed in the EA. It is anticipated that the EA will be available for public review early in 1999.

The land retirement goals of the USBR expanded program compare with the SJVDP 1990 Management plan recommendation to retire 18,000 acres of land in the Westlands subarea and zero acres within the Tulare subarea by the year 2000. By the year 2040, the recommendation was to extend retirement to a total of 33,000 acres in the Westlands subarea, and 7,000 acres in the Tulare subarea.

IV. TECHNICAL EVALUATIONS/RESULTS OF RRLRP AND OTHER ALTERNATIVES

A. HYDROLOGIC CONSEQUENCES FOR WATER CONSERVATION, DRAINAGE REDUCTION, AND SELENIUM REDUCTION

Agriculture in much of the Western San Joaquin Valley (WSJV) receives irrigation water from the Federal Central Valley Project (CVP). In enacting the Central Valley Project Improvement Act in 1992, Congress responded to the tension underlying land retirement by authorizing a program in which willing

sellers of land receiving CVP water, and located within the drainage problem area, could sell property to the Interagency Land Retirement Team (ILRT), although no authority was granted to retire land without the consent of the owner (Benson 1997). In order to evaluate land parcels offered to the ILRT, a set of selection criteria were developed. According to these criteria, the primary objective of any land acquisition is to reduce the quantity of agricultural drainage generated in the region. Mitigating the drainage problem associated with irrigated agriculture in the WSJV is the primary concern. Additional benefits of land retirement could include, however, habitat restoration for the threatened San Joaquin kit fox, giant kangaroo rat, blunt-nosed leopard lizard, and Nelson's antelope ground squirrel and long term preservation of the regional agricultural production base (Mays 1997). What follows is an investigation of system responses to different land and water use patterns in the context of the CVPIA land retirement program. This work was done at the specific request of the ILRT and addresses certain scenarios of interest to evaluate actual land retirement strategies. What emerged is a general framework for evaluating land retirement programs.

The drainage reduction, agricultural productivity, and habitat restoration effects of various land retirement strategies implemented on the west side of the San Joaquin Valley (Figure 1) were evaluated using a model (Purkey and Wallender 1998). The two-dimensional, vertical transect groundwater model (Purkey et al. 1998a, 1998b) was derived from a non-Dupuit formulation of transient, unconfined groundwater flow equations (Neuman and Witherspoon 1970, 1971) and configured for a portion of the Panoche Creek alluvial fan of the western San Joaquin Valley (Figure 1).



Figure 1. The Western San Joaquin Valley of California, Including the Major Hydraulic Infrastructure and the Location of Groundwater Modeling (each grid square is 640 acres).

The DFE model built upon a number of other modeling exercises, many of which took a regional view of hydrologic conditions and water management options. Seminal work by Belitz and colleagues (1992, 1995) described the hydrology and resource use across a large portion of the western San Joaquin Valley. In contrast to this regional effort, Purkey and colleagues studied a smaller area at higher spatial resolution to better understand the local effects of management options such as land retirement. Modeling work conducted by Wu and colleagues (1998) was similar in scope to this effort, although only Purkey et al. specifically investigated the effects of land retirement on habitat restoration and agricultural productivity. This involved translating the simulated depth to the water table along the transect (Figure 2) in the short (1000 days or approximately 3 years), medium (5000 days or approximately 13 years) and long term (18,250 days or 50 years) into indicators of habitat suitability and agricultural productivity. These results are compared to those reported by other investigators in later sections.



Figure 2. Deforming Finite Element Model Transect With Up Gradient (Field 3) and Down Gradient (Field 5) Parcels in Relation to the San Luis and Delta Mendota Canals, Water Table Elevation Contours, and the Drainage Infrastructure of the Panoche Drainage District.

DFE Model Background

Details of the Deforming Finite Element (DFE) model used to simulate aquifer conditions below a portion of the western San Joaquin Valley (WSJV) under a variety of land retirement scenarios are presented elsewhere (Purkey and Wallender 1998) and only a summary is provided herein. Five land retirement scenarios were simulated (Figure 3) along with a “no retirement” baseline. The “contiguous” scenarios mimic the retirement of the entire model transect while the “patchwork” scenarios retire either Field 3 (up grade) or Field 5 (down grade) as shown in Figure 2. These correspond to 640 acre (2.6 km²) township and range land sections. Within the contiguous and down grade scenarios, sub-scenarios related to the operation of installed sub-surface tile drains were also considered. The assumption that no new tile drainage system installation would occur was adopted. To simulate land retirement the aquifer recharge rate was set to 0.0 m/day for the entire 50 year simulation of a retired parcel.

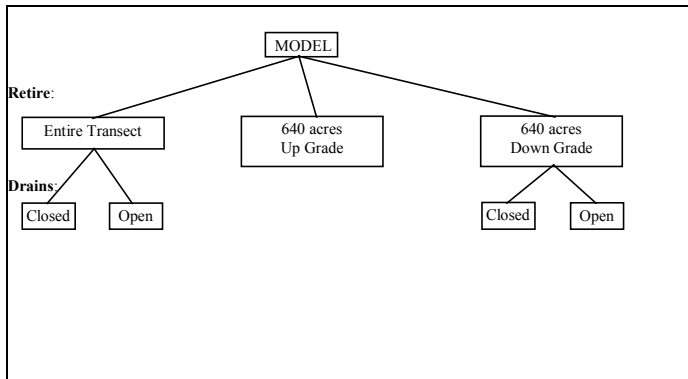


Figure 3. Simulated Land Retirement Strategies.

The 8.1 mi. (11.380 km) long transect from the groundwater divide to near the Delta Mendota Canal (Figure 2) extends down through the entire unconfined surficial aquifer to the top of the Corcoran Clay (Figure 4). Transects placed perpendicular to the ground surface contours on alluvial fans should encounter the typical patterns of concentric water table elevation contours (Figure 2). The soil texture varies from coarse at the upper end of the fan to fine down gradient on the fan along the model transect. The transect captures the essence of conditions on the coalescing alluvial fans which dominate the WSJV.

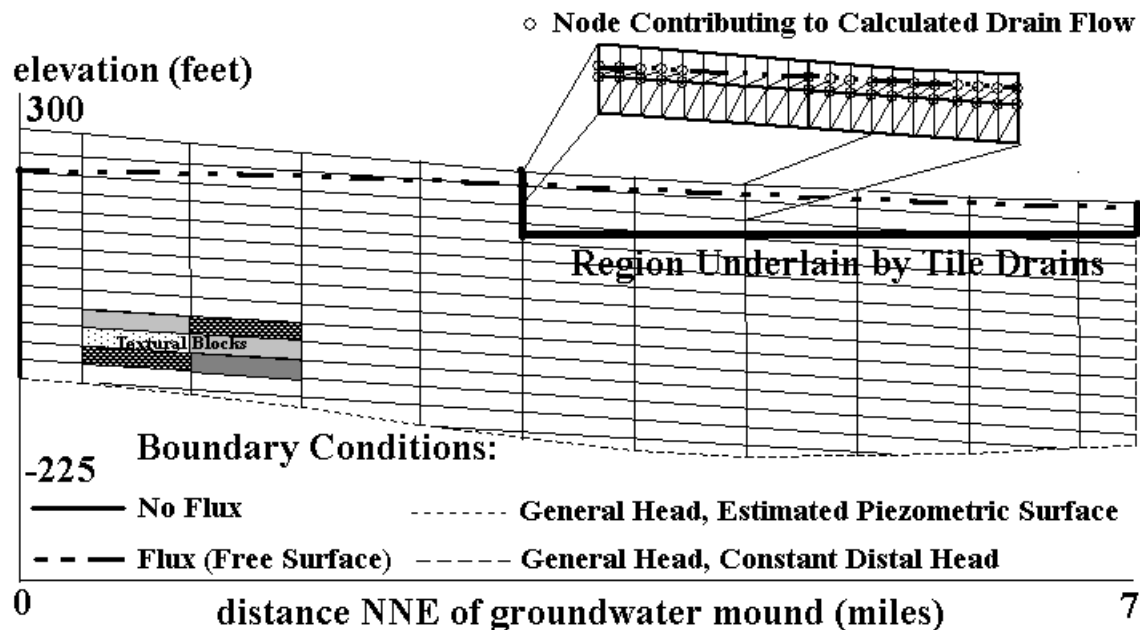


Figure 4. DFE Model Transect with Boundary Conditions and Drain Tile Node Locations (NNE is the direction North Northeast).

Extrapolating the available twelve year record of piezometric surface elevations in the confined aquifer below the Corcoran Clay over the entire 50 year retirement simulation was challenging. To construct a time series, the 12 year long USGS database of the piezometric surface elevation in October, 1972, 1976, and 1984 (Belitz and Phillips, 1992) was extended using water level measurements taken up to 1994 in the WWD (Westlands Water District) well (Figure 5) approximately 1.86 mi. (3 km) from the upgradient end of the transect. The rapid drop in the piezometric surface elevation corresponds with the 1987-1992 drought during which pumping from the confined aquifer increased. An additional 12 years of data came from repeating the pattern recorded in the USGS database, followed by extrapolation of the final rate of change elevation with time over the remaining 16 years. The form of the piezometric surface elevation captures the general recovery of the piezometric surface which has continued since the importation of surface water into the WSJV starting in the 1950s, and the potential interruption of this trend by a drought, characteristic of California's variable hydrology.

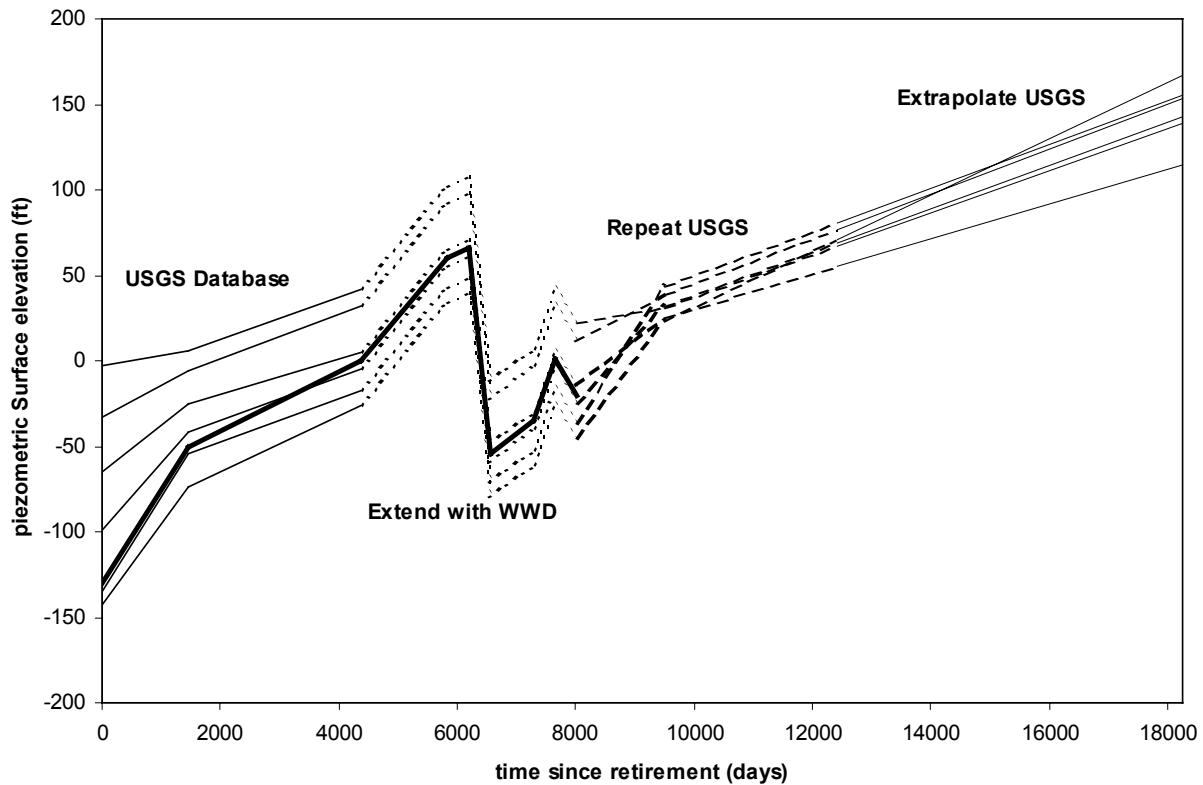


Figure 5. Assumed Evolution of the Piezometric Surface Elevation in the Confined Aquifer below the Corcoran Clay.

Lateral flow to the transect (flow perpendicular to the direction of the transect) is assumed zero for the two-dimensional model. To fully satisfy this assumption, fields perpendicular to the transect should be managed the same way as the field at the transect. The assumption is violated, for example, if fields lateral to a retired field are not retired because the lowering of the water table at the transect will induce lateral flow to the transect. The error is particularly large in the case of contiguous retirement, where a special quasi-three dimensional formulation of the DFE model has been adopted to mitigate the error. The potential modeling error suggests that simulated land retirement scenarios should be viewed as representations of the system response rather than absolute predictions of how the land retirement program would affect the prevailing hydrologic regime in the WSJV. In any case, the no retirement baseline simulation, which is not affected by this modeling assumption, is the reference for evaluating scenarios.

Drainage Reduction

As expected, annual drainage volume (also expressed as drainage depth which is drainage volume divided by area retired) was zero for the contiguous retirement scenarios when the drains are closed upon retirement (Table 1, rank 1 and Figure 6, top horizontal line). Note that in Figure 6 negative values indicate groundwater flow out the drains with increasingly negative values representing larger amounts of drainage. When drains are left open, drainage along the transect stops within 500 days of retirement (rank 2, top horizontal line). All patchwork scenarios reduce drainage relative to the no retirement baseline (annual drainage depth is 0.4 ft., Table 1) and reduction is greater for downgradient compared to up gradient retirement. When drains underlie the retired land, closing the drains increases slightly the simulated drainage mitigation potential. For maximum drainage reduction the preferred strategy is to retire a large contiguous area. In reality this could be very difficult to accomplish with a willing seller approach. If only a patchwork retirement strategy is viable, land lying down slope in the actively drained, shallow water table region of the transect offers the greater drainage mitigation potential.

Table 1. Absolute and Relative Drainage Reduction Potential Across the Entire Transect for Various Land Retirement Strategies (simulated).

Scenario	Code	Rank	Drainage Volume (ac-ft./yr.)	Drainage Depth (ft./year)	Percent Reduction
No land retirement	BL	6	56.4	0.4	0
Contiguous, drains open	CRDO	2	.23	N/A ¹ .	99.6
Contiguous, drains closed	CRDC	1	0	N/A	100
Up gradient	UG	5	47.4	0.34	16.0
Down gradient, drains open	DGDO	4	42.1	0.3	25.4
Down gradient, drains closed	DGDC	3	38.9	0.28	31.0

1. It is not possible to calculate the simulated drainage depth for the pseudo-three dimensional case without making assumptions about the disposition of the water table between the center line simulation and the no-retirement boundary.

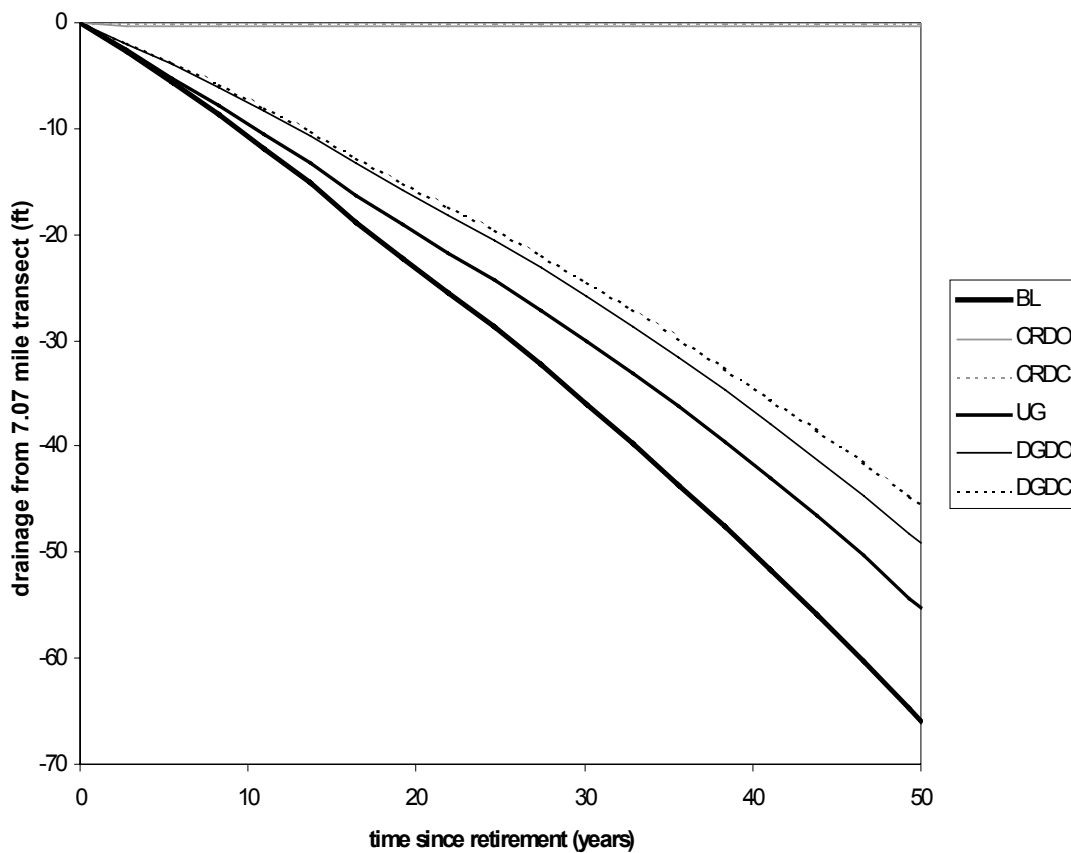


Figure 6. Simulated Cumulative Drainage Over 50 Years Under a Variety of Land Retirement Strategies: BL Baseline No Retirement; CRDO Contiguous Retirement Drains Open (nearly zero, Table 1); CRDC Contiguous Retirement Drains Closed (zero, Table 1); UG Up Gradient; DGDO Down Gradient Drains Open; DGDC Down Gradient Drains Closed.

Habitat Restoration

In addition to reducing the volume of drain water generated in the WSJV, a land retirement goal is to restore wildlife habitat. For suitable habitat the water table must not lie too close to the ground surface. A high water table below a retired parcel could lead to direct water table evaporation and the deposition of salt at the land surface (Section D.3). In addition to preventing salt deposition, a well aerated soil profile (low water table) will allow target terrestrial species to construct dry burrows conducive to successful breeding and rearing of young.

To define a well aerated soil profile, a threshold value of the depth to groundwater of 7 ft. (2.13 m) has been established based on empirical evidence

that water table evaporation is extinguished by this depth in Panoche Clay Loam soil (Nielsen et al. 1973). When the simulated water table below a retired parcel of land is deeper than this threshold, it is considered to have suitable habitat value. This depth, however, may be too shallow according to simulation results reported in Section D.3.

No Retirement Baseline

The simulated evolution of the water table profile for the no retirement baseline shows that the zone of shallow water continues to move up fan over the course of the simulation. The portion of the transect with a water table depth shallower than 7 ft. (2.13 m) expands in the up slope direction (Figure 7). The up gradient Field 3, which started as a well aerated parcel, eventually has a high water table by the end of the 50 year simulation, as well as a small portion of the field located immediately up slope. Without a change in management, the continued practice of irrigated agriculture in the WSJV is problematic.

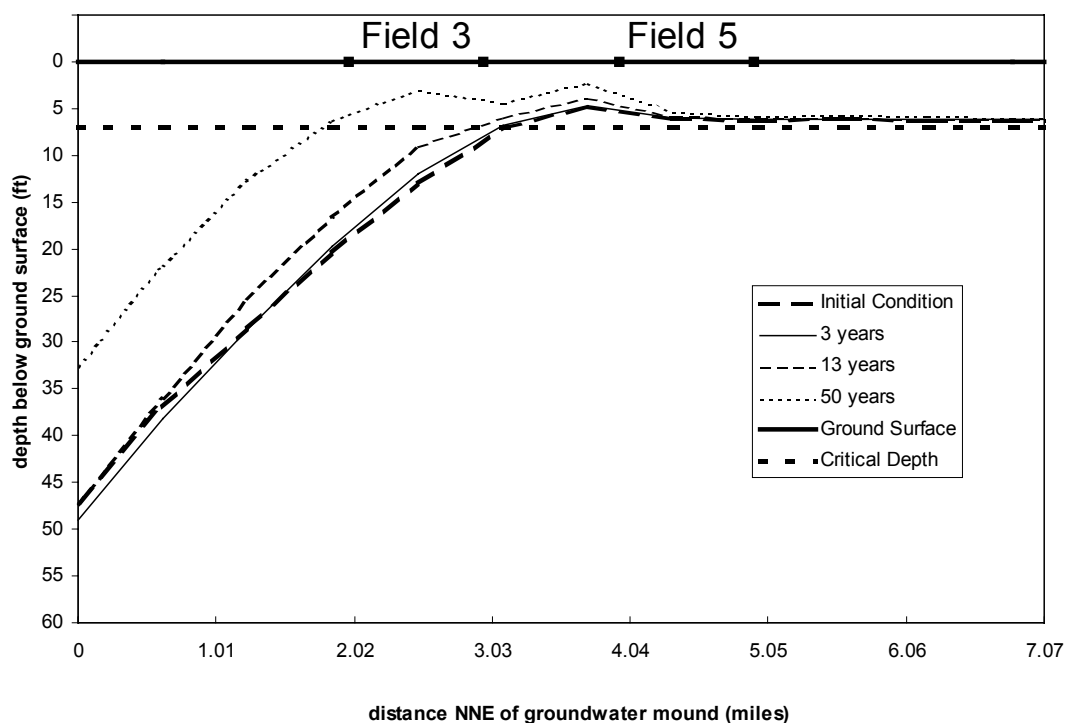


Figure 7. Simulated Depth to Groundwater Below the DFE Model Transect for the Baseline No Retirement Case After Approximately 3 Years (1000 Days), 13 Years (5000 Days), and 50 Years (18,250 Days).

Contiguous Retirement

For the contiguous retirement scenario, when the drains below the retired transect are left in operation the shallow water table disappears (Figure 8) within 1000 days of retirement. The entire transect lying along the center line of the quasi-three dimensional retirement area (Figure 9) is suitable habitat. This quasi-three dimensional formulation assumed that at some reasonable distance from the transect the water table would remain unaffected by retirement and would contribute lateral inflow to the transect. The water table rises between 13 and 50 years despite the lack of aquifer recharge (Figure 8). This is caused by the increase in piezometric pressure below the Corcoran clay (see Figure 5) coupled with sustained lateral inflow. The associated decrease in the hydraulic gradient reduces the magnitude of downward flow across the Corcoran clay relative to lateral inflow. This imbalance causes an increase in groundwater storage and the water table rises.

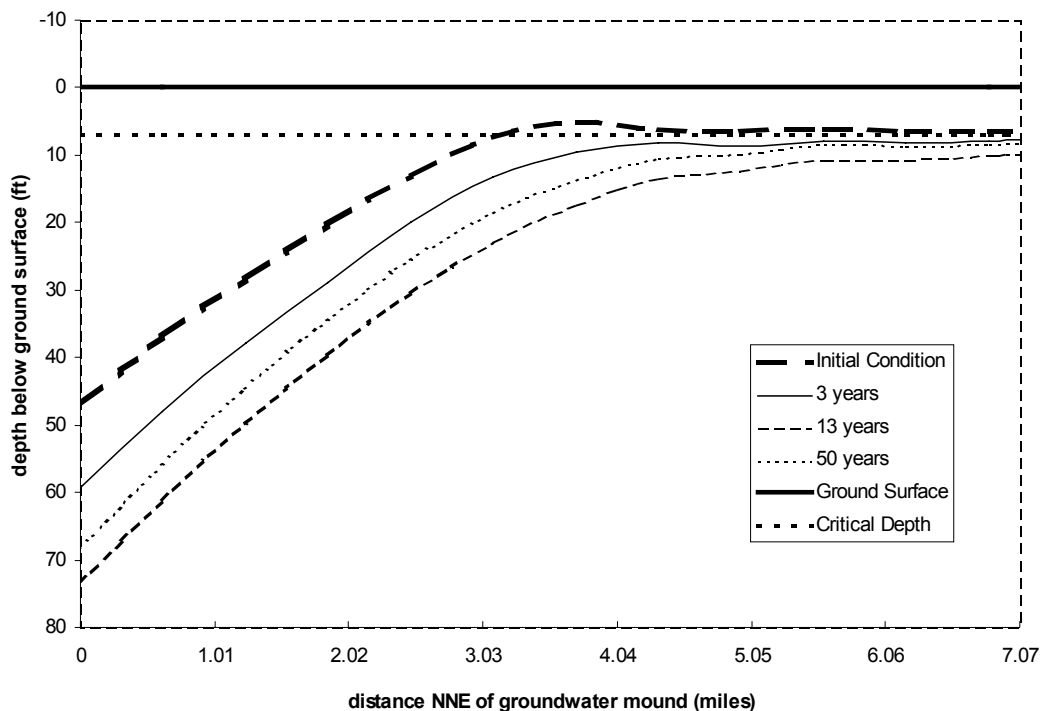


Figure 8. Simulated Depth to Groundwater for the Contiguous Retirement with Drains Open.

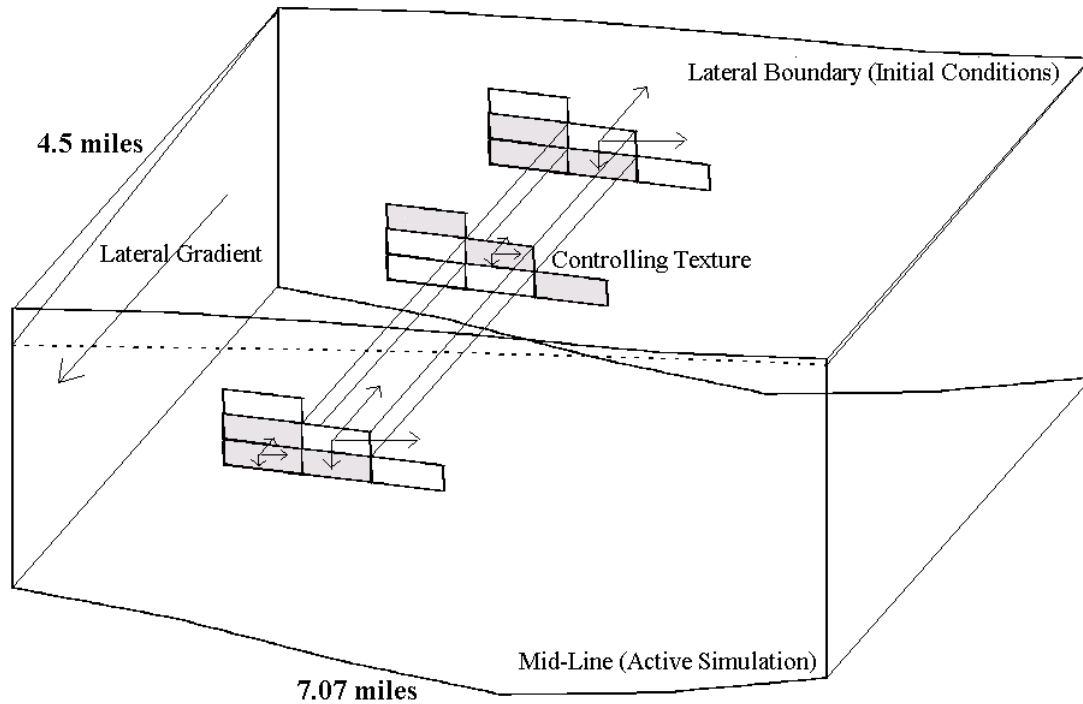


Figure 9. Quasi-Three Dimensional DFE Model Formulation Used to Simulate the Contiguous Retirement Strategy.

Up Gradient Patchwork Retirement

Retirement of Field 3 immediately up fan of the currently installed tile drainage network controls the up slope progression of the zone of shallow groundwater relative to the baseline (the light gray lines in Figure 10). The percentage of the transect having suitable habitat remains essentially constant over 50 year simulation.

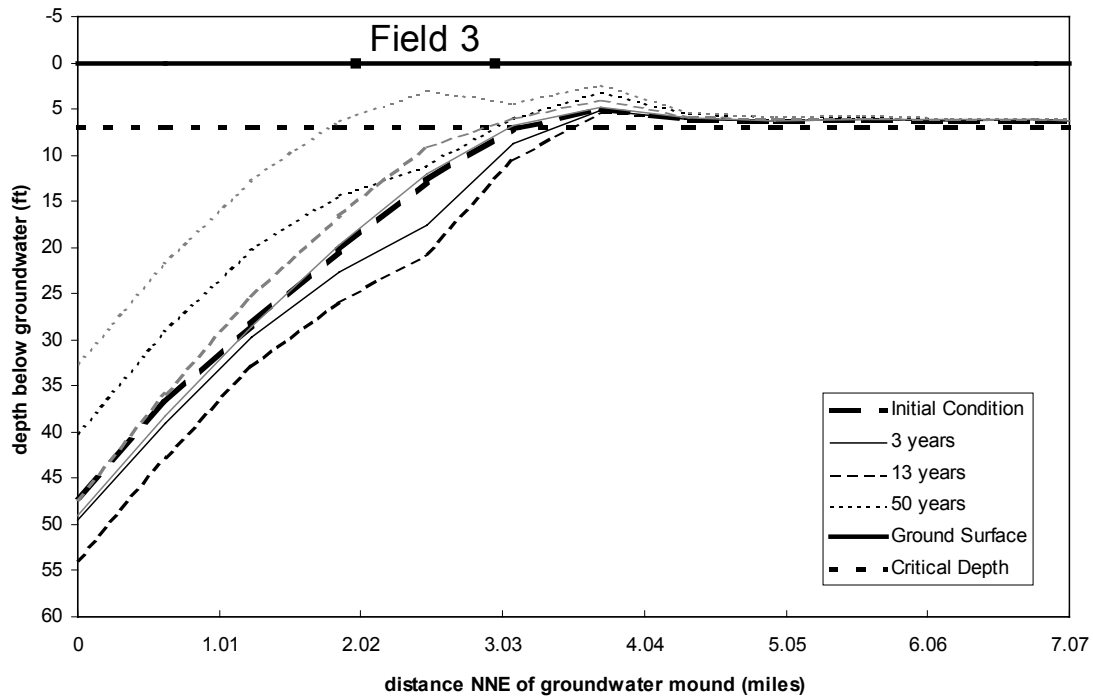


Figure 10. Simulated Depth to Groundwater for the Up Gradient Strategy.

Down Gradient Patchwork Retirement

Simulated retirement of Field 5, the most up fan fully drained section, does not create sustainable well aerated habitat. When the drains below Field 5 are left open, the simulated water table below the retired parcel initially falls below the threshold depth to groundwater of (7 ft.) 2.13 m. After 3 years, the simulated water table is below both the baseline profile and the 7 ft. (2.13 m) threshold (Figure 11). Thereafter the water table rises above the threshold and by 13 years while still below the no retirement baseline, the water table is above the critical threshold. In the long term no habitat is gained under this retirement scenario with or without the closure of the field drains.

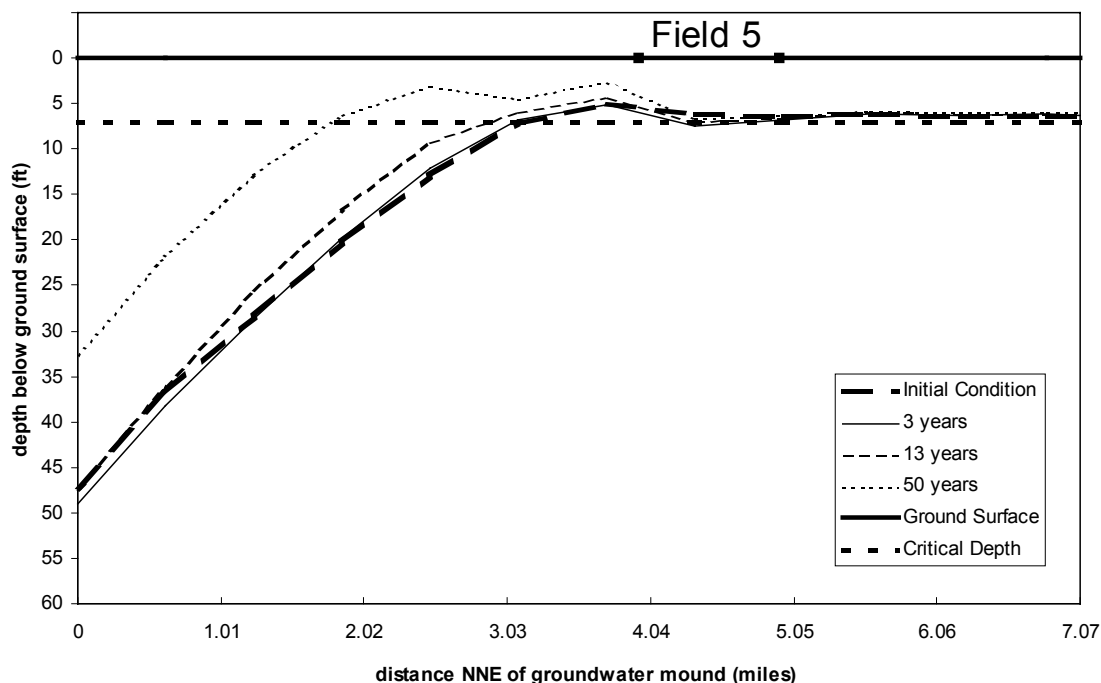


Figure 11. Simulated Depth to Groundwater for the Up Gradient Strategy.

Maximum Habitat Value

A deep, well drained unsaturated soil profile can provide useful habitat for threatened terrestrial organisms. Shallow groundwater (less than 7 ft.) can cause soil water logging and salt accumulation which degrade habitat value (see Rhodes et al., Section D.3). Precipitation over the retired parcel will tend to counteract this effect. Water extraction by plant roots may tend to accentuate it. More modeling and field studies are needed to determine if 7 ft. is sufficient to prevent upward movement of salt into the root zone.

Results showing the percentage of the transect with the water table deeper than 7 ft. (2.13m) are summarized in Figure 12 for the near- (3 years), medium- (13 years), and long-term (50 years). Less habitat is restored and sustained when down gradient fields are retired compared to up gradient fields. At the moment of retirement, there is no benefit of retiring Field 5 with the drains open or closed (DGDO, DGDC) because the field has a shallow water table. After 3 years the water table falls below 7 ft. (2.13 m) in a portion of the retired parcel and this portion is enhanced by leaving the drains open. The continued

increase in piezometric pressure below the Corcoran Clay layer, however, causes the water table to rise in the longer term and the habitat gains are lost.

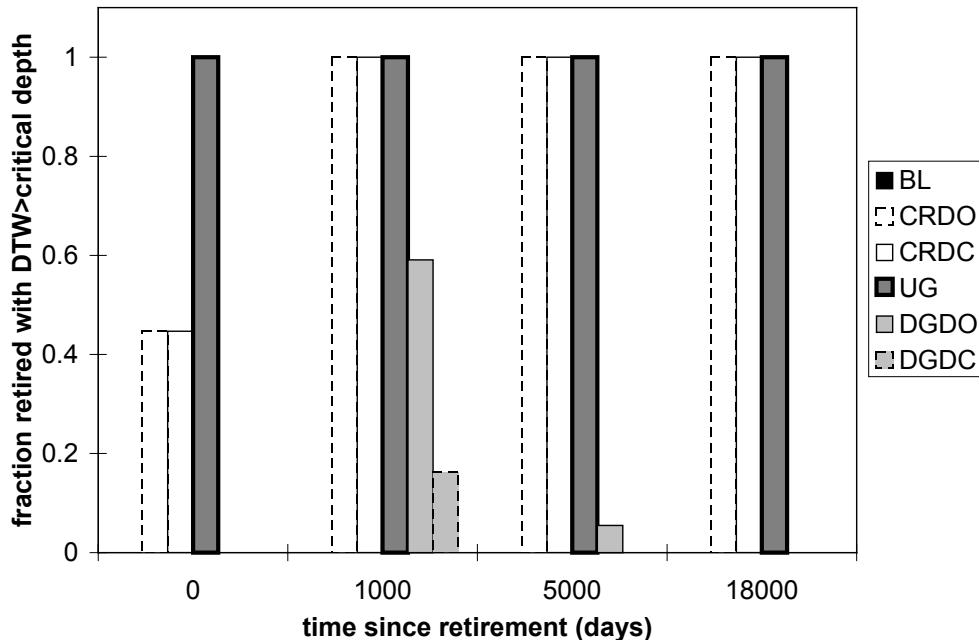


Figure 12. Simulated Evolution Of Percent Of Land With A Water Table Deeper Than 7 ft. (2.13 m) For Land Retirement Strategies.

The comparative advantage of each land retirement scenario in terms of creating habitat value is summarized in Table 3 and Figure 12. Recall that if the water table under the retired land is deeper than 7 ft., the habitat is classified as suitable. If entire parcel is underlain by suitable habitat, then the fraction in Figure 14 is one which is the case for up gradient retirement scenario which is ranked number one (Table 3). Thus, by retiring up gradient land, a greater fraction of the transect is suitable, in the short and long term, for habitat compared with down gradient retirement strategies. At the moment of its retirement, Field 3 (UG) lies up slope of tile drains and is free from the habitat degradation associated with a shallow water table. According to the simulations, it remains well aerated throughout the intervening 50 years because the water table depression below Field 3 delays up slope encroachment of the shallow water zone. The contiguous retirement scenario also results in immediate suitable habitat enhancement along the center line of the up slope area but would require approximately two years in the down-fan area.

Table 2. Simulated Value of the Habitat Restoration Proxy of Various Land Retirement Strategies Along with the Resulting Ordinal Values.

Scenario	Code	Rank	Temporal Average Habitat Benefit ¹
No land retirement	BL	5	0
Contiguous, drains open	CRDO	2	0.861
Contiguous, drains closed	CRDC	2	0.861
Up gradient	UG	1	1.0
Down gradient, drains open	DGDO	3	0.161
Down gradient, drains closed	DGDC	4	0.041

1. The temporal average habitat benefit is the average of the four values plotted in Figure 12.

Sustained Agricultural Productivity

In carrying out a land retirement program another goal is to minimize the adverse impact on agricultural production and the economy of the WSJV. For these simulations we assume that the retirement of one unit of land will have the same impact on the local economy, whether it is part of a contiguous area or an isolated section. Retiring this land will also affect the water table disposition and therefore the productivity of land along the transect that remains in production. The percentage of the transect which remains actively irrigated and undrained with a water table below 7 ft. (2.13 m) is the criteria used to assess suitability for agricultural production. For example, the percentage is zero for the contiguous retirement scenario. Although the water table is deeper than 7 ft., none of the land is irrigated.

Results for the scenarios are shown Figure 13 for the near-, medium- and long-term. By retiring an up gradient parcel, Field 3 (UG), there is an immediate decline in agricultural productivity because land is taken out of production because this parcel was initially unaffected by shallow groundwater. In the short term eliminating non-drainage impacted land is immediately deleterious to the agricultural productivity; in the long term the up slope field is the preferred option. This certainly highlights the importance of comparing short and long term economic impacts as discussed in Section D.4.

As shown in Figure 10, retirement of Field 3 suppresses the water table under the undrained portion of the next field down the fan. It is sufficient to move the water table below the 7 ft. (2.13 m) threshold. In the long term, this down slope suppression is not maintained, although all well aerated land above Field 3 remains free from shallow groundwater throughout the simulation.

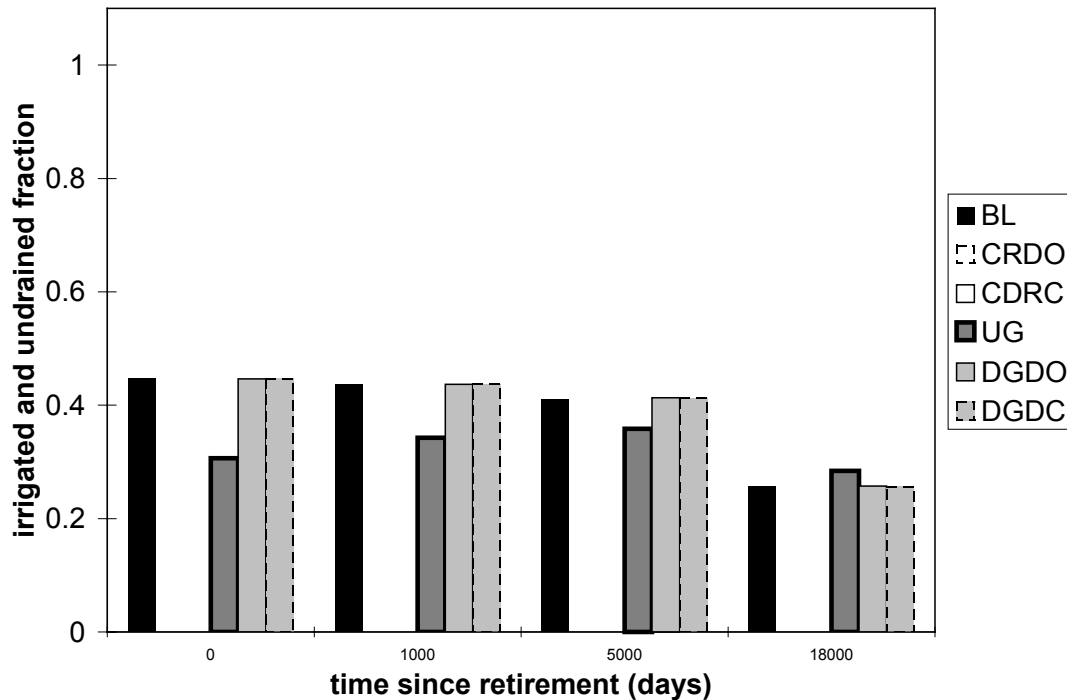


Figure 13. Simulated Evolution of the Agricultural Productivity, the Fraction of Total Transect Which Remains Irrigated and Undrained

In the case of down gradient retirement (DGDO, DGDC), the response is quite different. Removing Field 5 from production had no impact on the amount of well aerated, irrigated and undrained land remaining in production because it was drained. Its initial fraction is the same as that of the baseline no retirement scenario in which no undrained land is retired. With time, however, productivity declines for both the base line and the down gradient scenarios because the zone of shallow groundwater expands up slope until it underlies both Field 3 and a portion of the adjacent up slope neighbor. This represents a loss in productivity because Field 3 is initially irrigated and undrained in this scenario.

In the short-term, more land is kept productive by retiring down gradient field than by retiring up gradient fields. In the long term more land is kept productive by retiring the up gradient field compared to the down gradient field because the increase in piezometric pressure below the Corcoran Clay causes the water table to rise, even in the upslope reaches of the transect. By forestalling the up slope migration of the shallow water table zone, retirement of an up gradient parcel actually protects the two fields located up slope along the transect from future degradation. For the no retirement baseline and down gradient retirement options, the margins of these fields eventually come into proximity with the simulated high water table zone.

Agricultural productivity results are summarized in Table 4. Recall that agricultural production is classified as sustainable if the water table is deeper than 7 ft. below irrigated land. The fraction expressed in Table 4 is the proportion of entire transect which meets this criteria. For example, in the case of down gradient retirement 0.437 of the transect remains productive after 3 years resulting in a number one ranking (Table 3). After 18,250 days (50 yrs.) the ranking falls to two and three for the drains open and closed cases, respectively. At that time the up gradient retirement scenario is ranked number one because 0.294 of the transect remains productive. This time dependent result demonstrates the challenge of choosing between the short- and long-term benefits and costs of different land retirement strategies. As in many resource management situations the problem reduces to balancing short term economic gain with long term sustainability. Growers appreciate the higher return for such an investment in later years. For example in recent years a large number of orchards and vineyards have been planted on the up slope regions of the alluvial fans in the WSJV. These added income benefits, however, may not outweigh the added drainage and habitat costs.

Table 3. Simulated Agricultural Productivity for Various Land Retirement Strategies After Approximately 3 Years (1000 Days) and 50 Years (18,250 Days).

Scenario	Code	Fraction Transect Irrigated and Undrained			
		1000 Days		18,250 Days	
		%	Rank	%	Rank
No land retirement	BL	.436	2	.246	4
Contiguous, drains open	CRDO	0	4	0	5
Contiguous, drains closed	CRDC	0	4	0	5
Up gradient	UG	.342	3	.294	1
Down gradient, drains open	DGDO	.437	1	.257	2
Down gradient, drains closed	DGDC	.437	1	.256	3

Comparisons with Other Modeling Exercises

Using a regional groundwater model which covered approximately 550 mi² of the Little Panoche, Panoche, and Cantua Creek alluvial fans, Belitz and Phillips (1995) reported similar results. These authors simulated down gradient land retirement on the 224, 1 mi² horizontal cells underlain by a shallow water table (less than 7 ft. or 2.13 m) at the start of the simulation. In a manner akin to down gradient retirement in the DFE, when these cells received no further recharge during a 50 year simulation, the water table fell below the 7 ft. (2.13 m) threshold. Unfortunately, the up slope growth of the zone of shallow groundwater continued under this scenario as an additional 107 mi² of up gradient land experienced the onset of water logging over the course of a

50 year simulation (as compared with 120 cells under a no retirement baseline simulation). This result is similar to the simulated DFE water table response during down slope retirement shown in Figure 11.

Under a checker board pattern of land retirement on the 224 mi² of degraded down gradient land, an additional 117 mi² of land became water logged, while non-retired cells surrounded by retired cells experienced only a 3% decline in drainage. In the DFE model this is akin to evaluating drainage reduction from Fields 4 and 6 when Field 5 is retired. In the current analysis, which has greater field to field numerical refinement, simulated drainage reduction from unretired fields exceeds that reported by Belitz and Phillips. According to Table 4, retirement of Field 5 with the drains left open, reduces the simulated short term drainage in Field 4 by 11.2% and in Field 6 by 7.1%. In the long term, the drainage reduction from these fields range from 3.1% to 4.4%, respectively.

Table 4. Simulated Drainage Rate Reduction from Drained Fields 4 and 6 when Up Slope Field 3 and Adjacent Field 5 are Retired, in ft./year.

		Years Since the Start of the Simulation		
		3	13	50
Field 4	Baseline	.438	.766	1.544
	Retire Field 3	.304	.310	.880
	% change	-30.6	-59.5	-42.9
	Retire Field 5, close drains	.405	.734	1.555
	% change	-7.6	-4.1	0.8
	Retire Field 5, leave drains	.390	.712	1.496
	%change	-11.2	-7.2	-3.1
Field 6	Baseline	.661	.748	.887
	Retire Field 3	.653	.726	.872
	% change	-1.1	-2.9	-1.6
	Retire Field 5, close drains	.628	.730	.905
	% change	-4.7	-2.4	2.2
	Retire Field 5, leave drains	.613	.708	.847
	%change	-7.1	-5.44	-4.4

Belitz and Phillips did not comment upon the retirement of currently undrained land, up slope of the zone of shallow groundwater. This is the scenario investigated through the simulated up gradient retirement of Field 3 (see Figure 10). In this case, the further up slope progression of shallow groundwater was arrested and actively irrigated up slope land remains free from a shallow

water table. This strategy also produced a dramatic reduction in drainage from Field 4, immediately downstream from the retired land (see Table 4) ranging from 30.6% to 42.9% after approximately 3 years and 50 years, respectively.

The results of Wu's simulations (1998) suggest a similar hydrologic response to land retirement. Contiguous retirement of both up and down gradient lands is the most effective method of lowering the water table and reducing drainage (0.049 ft./year as opposed to 0.706 ft./year in a baseline simulation). When only a portion of a transect along an alluvial fan can be retired, down slope retirement (0.539 ft./year) more drastically reduces drainage than up slope retirement (0.563 ft./year). Up slope retirement, however, does stem the expansion of the zone of shallow groundwater.

B. BIOLOGICAL CONSEQUENCES FOR WILDLIFE HABITAT

Introduction

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The 1990 *Final Report on San Joaquin Valley Agricultural Drainage* (SJVDP 1990)) did not address potential benefits of agricultural land retirement to wildlife resources, other than those which would accrue from site-specific (and presumably overall) reductions in the quantity and toxicity of drainwater associated with removal of the most contaminated soils from the irrigation pattern. In particular, the potential for retired agricultural lands to support wildlife habitat was not considered. Given the dramatic decline in native habitats in the Central Valley, the contributions that could be made to restoring habitat through this program are substantial.

This discussion is primarily concerned with the potential for retired lands to function as upland habitat. A number of San Joaquin Valley biotic communities can be classified as upland, including Valley Saltbush Scrub, Valley Sink Scrub, Non-native Grassland and Valley Sacaton Grassland. Upland habitat refers only to dry-land habitats, not wetlands, and can occur on either upslope, downslope, upgradient or downgradient lands. Riparian and other wetland communities also have been lost and degraded by land conversion in the San Joaquin Valley, but restoration of these communities on drainage-impacted lands would likely result in problems similar to those that caused birth deformities and mortality in waterfowl at the Kesterson National Wildlife Refuge (Ohlendorf 1989, Presser and Ohlendorf 1987, Presser et al. 1994, Skorupa 1998). Conservation and recovery of wetland communities is generally being addressed on lands that do not have significant drainage and contamination problems. The restoration of retired agricultural lands to upland habitat is a featured recovery strategy in the recently published *Recovery Plan for Upland Species of the San Joaquin Valley, California* (USFWS 1998).

While large-scale wildlife habitat preservation is a familiar and well-developed science, the restoration of habitat on previously disturbed sites is a relatively new pursuit. The latter has mostly been applied to riparian systems, marshlands, upland habitats, and forested areas, and has generally been associated with erosion management, forest or rangeland improvement, and waterfowl and/or wild game management (e.g., restoration of marshlands for ducks and the widespread planting of forage plant species for upland and large game). Restoration of smaller sites has been sought in a variety of situations, mostly in attempting to rectify site-specific problems of erosion or contamination, accomplish mitigation for development projects, or for recreation associated wildlife management. Only within about the past two decades have attempts been made to restore larger tracts of habitat for general and multi-species wildlife benefit or for sensitive species recovery.

In the past 150 years, the progression of San Joaquin Valley land use has favored conversion of land from wildlife habitat into more intensive human-associated uses (Preston 1981). As such, it is not surprising that long term experience relevant to the recovery of large expanses of biotic communities once

common in the San Joaquin Valley is virtually nonexistent. Despite that information shortfall, there still exists some (albeit shorter-term) information to suggest that retiring previously cultivated, highly saline, and poorly drained lands in the San Joaquin Valley could lead to restoration of wildlife habitat (Uptain 1995).

The quality of the developing habitat would be closely dependent on the parameters of land location, soils, level of present and future contamination, tract size and connectivity, elevation, climate, hydrology, microtopography, adjacent land uses, site management, timing, and possibly other factors. These are among the criteria for selection of retired lands according to the interim guidelines issued by the interagency land retirement team (USDI 1997). While an analysis of potential lands for retirement suggests that these parameters can be favorably manipulated in at least some cases, it remains uncertain how the lands will actually perform in both the short and long term. Therefore, as efforts are made to identify prospective sites and initiate the process of habitat restoration, careful monitoring will be essential to determine whether or not the lands are actually contributing benefits to wildlife. Moreover, in-depth monitoring will be needed to guard against the occurrence of a wildlife “demographic sink”.

Care must be taken to ensure that retired lands are actually a benefit to wildlife rather than a detriment. While retired and restored lands may visually appear to provide adequate habitat characteristics, they may actually represent an “attractive nuisance” and therefore a net loss to regional wildlife populations. Such circumstances could arise with site contamination, adverse surface or groundwater hydrology, adverse adjacent land uses, isolation, or other site-specific factors. Additionally, the alternative uses of conserved water may have adverse off-site wildlife consequences, which will require ongoing evaluation as the allocation of water proceeds. Any program of land retirement and restoration should therefore proceed only with adequate monitoring protocols and designed-in alternatives to respond rapidly to adverse circumstances, should any develop. Accordingly, *adaptive management*, the process of linking management and monitoring in a research framework (Holling 1978, Walters and Holling 1990, Noss and Cooperridder 1994), is a required theme in the restoration of retired farmlands.

The absence of long-term experience with large scale habitat restoration on disturbed sites should not necessarily be construed as a constraint, but rather as an opportunity to proceed with an evaluation-level program of land retirement and cautious wildlife habitat restoration. Recovery of San Joaquin Valley wildlife is inextricably linked to the recovery of the ecosystems on which they depend. Given the strong development history of the valley and its dependent economics and demographics, there is an impetus to develop programs that can efficiently accomplish ecosystem recovery with minimal impacts to other beneficial uses of land and water. A properly designed and managed program of land retirement could be such a program, with significant potential to contribute to regional land use and societal objectives.

Biotic Communities Historically Occurring within the Program Study Area

Historical vegetation in the lowlands of the central San Joaquin Valley consisted of a mosaic of intermixed communities. Their extent and distribution varied dramatically with seasonal fluctuations in the wetlands created by an abundance of winter rains and spring snow melt from the Sierra Nevada (Griggs et al. 1987). The wetlands have now been drained and the land converted to agriculture. The runoff is impounded in numerous reservoirs and diverted to provide water for the growing agricultural economy and increasing urbanization of the Valley. Some small areas of upland habitat remain that provide insight into what once dominated the landscape, although their character has changed because of the introduction of Mediterranean plant species which followed California's colonization (Wilkens 1993) and the elimination of native herbivores that once grazed on the highly productive grasslands (Heady 1977).

Griggs et al. (1987) recognized twelve plant associations as occurring historically in the Tulare Basin. These associations can be lumped into 6 general categories: Valley Saltbush Scrub, Non-native Grassland, Valley Sink Scrub, and Valley Sacaton Grassland, Valley Riparian Forest, and Valley Freshwater Marsh. The composition of these habitat types are determined by various abiotic and biotic factors including soil type (e.g., particle size, compaction, alkalinity, soil depth, water table depth, and drainage), amount of local precipitation, adjacent land use, historic site disturbance, and other factors. They can be generally described as follows:

Valley Saltbush Scrub: This biotic community is relatively open (10 to 40% cover) and is composed of a chenopod shrub overstory with a low herbaceous annual understory. The overstory is dominated by *Atriplex polycarpa* or *A. spinifera*. Most perennials (except *A. spinifera*) flower from May to September. The annuals (and *A. spinifera*) flower from January through April. Characteristic plant species include: *Atriplex polycarpa*, *A. spinifera*, *A. phyllostegia*, *Delphinium recurvatum*, *Frankenia salina*, *Isocoma acradenius bracteosus*, *Gilia tricolor*, *Hemizonia pungens*, and *Platystemon californicus*.

Valley Saltbush Scrub typically is found on rolling, dissected alluvial fans with sandy to loamy soils without surface alkalinity. This habitat type was once extensive in the southern and southwestern San Joaquin Valley and the Carrizo Plains of San Luis Obispo County, but probably occurred only along the margins of the project area because of its affinity to relatively well-drained, non-alkaline soils (Holland 1986). Accordingly, restoration of retired agricultural lands to Valley Saltbush Scrub habitat would not be practical in most cases.

Non-native Grassland: This community consists primarily of introduced annual grasses, mostly of Mediterranean origin, with flowering culms from 0.2 to 1 m high or greater, depending upon seasonal rainfall. There are often numerous species of showy-flowered, native annual wildflowers, especially in years of favorable rainfall. The structure and species composition varies annually depending on amount and timing of precipitation. The grasslands usually are composed of a mosaic of floristic elements created by varying precipitation, slope aspect, soil types, intensity of grazing, and other factors. Germination occurs with the onset of the late fall rains; growth, flowering, and seed-set occur from winter through spring. With a few exceptions, the grasses and wildflowers dry and disarticulate with the increasing temperatures and decreasing moisture brought on by summer. Characteristic plant species include: *Avena barbata*, *A. fatua*, *Bromus hordeaceus*, *B. diandrus*, *B. madritensis*, *Erodium botrys*, *E. cicutarium*, *Eschscholtzia californica*, *Gilia* spp., *Hemizonia* spp., *Lasthenia* spp., *Layia* spp., *Lolium multiflorum*, *Lupinus* spp., *Lepidium nitidum*, *Medicago hispida*, *Nemophila menziesii*, *Orthocarpus* spp., *Phacelia* spp., *Schismus arabicus*, *Vulpia myuros*, and *V. microstachys*.

Non-native Grasslands occur on fine-textured, usually clay soils, which are moist or even waterlogged during the winter rainy season and very dry during the summer and fall. However, these grasslands also commonly occur on sandy soils and on soils that are relatively high in salinity. Non-native grasslands usually comprise the understory component of Valley Saltbush Scrub, or sometimes the two plant associations are intermixed in a mosaic pattern. Oak Woodland is often found adjacent and intermixed with these grasslands on moister, better-drained soils. Because this plant community occurs on a variety of soil types and will tolerate and even thrive in relatively high alkaline conditions, it would be a suitable plant community to establish on retired agricultural lands. Further, non-native grasslands are easily established on disturbed sites (Anderson 1987, Stromberg and Kephart 1996).

Valley Sink Scrub: This is a low growing shrubland plant community that is dominated by alkali-tolerant native species of Chenopodiaceae, especially *Allenrolfea occidentalis*, *Kochia californica*, or *Suaeda moquinii*. Understories usually are lacking, though a sparse herbaceous cover dominated by *Bromus rubens* or *Schismus arabicus* occasionally develops. The perennial shrubs flower from March to September, while the annuals mostly flower from January to April. Characteristic plant species include: *A. occidentalis*, *Delphinium*

recurvatum, *Distichlis spicata*, *K. californica*, *Lasthenia chrysantha*, *L. ferrisae*, *Nitrophila occidentalis*, *Salicornia subterminalis*, *Sporobolus airoides*, *Suaeda moquinii*.

This plant community grows on heavy, saline and/or alkaline clays of lakebeds and playas. High ground water supplies provide capillary water for the perennials. Soil surfaces often have a brilliant white salty crust over dark, sticky clay, and numerous alkali playas or scalds that hold standing water during the winter and spring may be present. This plant community may be intermixed with Valley Saltbush Scrub and grasslands on sites that are less alkaline. Valley Sink Scrub formerly surrounded the large San Joaquin Valley lakes (Tulare, Kern, Buena Vista, and Goose lakes) and occurred from the southern San Joaquin Valley north along the trough of the San Joaquin Valley into Sacramento Valley (Solano to Glenn County, west of the Sacramento River). However, it is now essentially extirpated due to agricultural development and ground water pumping. This plant community should thrive on retired agricultural lands. Preliminary studies indicate that many of the shrub species included in this plant association have relatively high germination success when used to revegetate disturbed sites (G. Cooley, pers. comm.).

Valley Sacaton Grassland: The aspect of this plant community is one of mid-height (up to 3 feet high) tussock-forming grassland which is dominated by *Sporobolus airoides*. Characteristic plant species include: *Distichlis spicata*, *Hordeum depressum*, and *S. airoides*. Valley Sacaton Grassland grows on fine textured, poorly drained, usually alkaline soils. Most sites have seasonally high water tables or are subjected to winter flooding. It often co-occurs with Valley Sink Scrub, Alkali Meadow, or Northern Claypan Vernal Pool plant communities. Its distribution, which was formerly extensive in the Tulare Lake Basin and along the San Joaquin Valley trough north to Stanislaus and Contra Costa Counties, has been much reduced. This plant community should do well on retired agricultural lands. Sacaton has been planted with great success in areas where the soil is sufficiently moist (G. Cooley, pers. comm.).

Valley Riparian Forest: This community is a composite of several types described by Holland (1986) including Great Valley Mixed Riparian Forest, Great Valley Oak Riparian Forest, and Great Valley Cottonwood Riparian Forest. These plant associations commonly intergrade with one another, and are distributed based upon distance from the water source and occurrence of sub-surface water. All are broad-leaved, winter deciduous, closed-canopy forests dominated by a variety of species including *Populus fremontii*, *Salix goodingii*, *Acer negundo*, *Juglans hindsii*, *Platanus racemosa*, and *Quercus lobata*.

Valley Riparian Forests occur on fine-grained alluvial soils near perennial or nearly perennial streams that provide sub-surface irrigation even when the channel is dry. They were formerly extensive on low-gradient, depositional reaches of the major streams throughout the San Joaquin Valley, but have been virtually eliminated by agricultural and urban development. Because of the lack of fresh water, the generally high alkalinity of the soils, and the potential for accumulation of toxic compounds, this community would not be appropriate for restoration on retired agricultural lands. However, small stands of trees should be planted under certain circumstances to help alleviate high groundwater or surface water build-up. Such a vertical component would provide excellent habitat for wildlife, especially raptors.

Valley Freshwater Marsh: This plant community is dominated by perennial, emergent monocots that grow to 4 or 5 meters tall. The plants often form completely closed canopies. Characteristic plant species of this community include: *Carex lanuginosa*, *C. senta*, *Cyperus esculentus*, *C. eragrostis*, *Eleocharis spp.*, *Hydrocotyl verticillata triradiata*, *Limosella aquatica*, *Phragmites australis*, *Scirpus acutus*, *S. americanus*, *S. californicus*, *S. robustus*, *Sparganium eurycarpum*, *Typha angustifolia*, *T. domingensis*, *T. latifolia*, and *Verbena bonariensis*.

This community requires quiet, permanent fresh water. The prolonged saturation permits accumulation of deep, peaty soils. Valley Freshwater Marsh habitat is distributed occasionally along the coast and in coastal valleys near river mouths and around the margins of lakes and springs. It is most extensive in the upper portion of the Sacramento-San Joaquin River Delta and common in the Sacramento and San Joaquin Valleys in river oxbows and other areas on the flood plain. It can also be found along the Colorado River on the California-Arizona border. Its occurrence is much reduced in area through its entire range. This community would not be preferred on retired agricultural lands because of the high potential for accumulation of toxic compounds in the aquatic food chain resulting in potential hazards to wildlife (Presser and Ohlendorf 1987).

Occurrence of Existing Habitat

Many native habitats of the San Joaquin Valley have declined dramatically in size and quality with the rise of an economically prosperous agricultural industry along with urban development (Preston 1981, SJVDP 1990). Small areas of upland habitat exist in scattered, isolated locations throughout the project area where they have been protected from urban and agricultural development or are only marginally suitable for agricultural development because of hydrologic and soil conditions or lack of sufficient irrigation water. Estimates of land available for wildlife range from approximately 345 to 572 square miles within the project area of approximately 2,706 square miles (Figures a, b). These estimates include not only native lands, but also rangeland and agricultural lands in production on a rotational basis. Many of

these areas have been degraded by grazing, off-road vehicle use, past dryland farming, rotational farming, flooding, and other uses and are generally not considered to be prime habitat for wildlife. Accordingly, the actual amount of native land available to wildlife is unknown, but is thought to be less than 10% of what originally occurred in the project area. The extreme loss, fragmentation, and degradation of these remaining wild land parcels have substantially contributed to many endemic plant and wildlife species of the Valley being listed as endangered, threatened, or vulnerable (USFWS 1998).

The Potential of Retired Lands to Benefit Wildlife

One of the potential benefits of land retirement which was identified in the 1990 SJVDP report was the decreased exposure of wildlife to toxic constituents in agricultural drainwater. Irrigated agricultural practices on drainage-poor lands often produce a subsurface drainwater which must be removed from the farmed land and disposed of at an off-site location. Subsurface agricultural drainwater that is high in selenium has been shown to have toxic effects on wildlife, particularly aquatic life and waterfowl, when at or above 5 ppb (Ohlendorf 1989, Skorupa 1998, Skorupa and Ohlendorf 1991). Selenium discharge into wetlands has caused significant impacts to migrating and breeding shorebirds in the San Joaquin Valley and elsewhere in the form of decreased hatching success, teratogenesis, and other deformities (Ohlendorf et al. 1987; Ohlendorf et al. 1988b; Pavaglio et al. 1997, Presser et al. 1994, Skorupa and Ohlendorf 1991). One of the anticipated benefits of the land retirement program is reduced selenium exposure to wildlife through reductions in the volume and levels of selenium in drainwater (USDI 1997).

Imported irrigation water from the Sacramento-San Joaquin Delta has greatly expanded the reach of agriculture in the San Joaquin Valley, and dramatically altered the Valley's appearance (Preston 1981). Native lands have been "reclaimed" to provide for a growing population and largely converted to agriculture. Native lands, or lands that have similar types of communities as native lands, are greatly valued for their contribution to the general biodiversity of the Valley. The replacement of native lands by intensely cultivated agricultural land greatly reduces biodiversity by replacing habitat that is composed of a variety of communities with habitat that is as close to a monoculture as possible. In addition, agricultural practices in the San Joaquin Valley, for the most part, maintain bare soils along ditch banks, between fields, along roads, and in orchards and vineyards. Rivers and sloughs that historically flowed into the Valley have been greatly modified, not only in flow regimes, but also by the clearing of native vegetation on a regular basis (Griggs et al. 1987). All of these practices have drastically reduced the amount of habitat available to wildlife in the Valley.

While agricultural lands are used by some species of plant and animals, many of those that thrive are invasive, non-native species. A few species of

native wildlife can usually be sustained in an area with agricultural lands as long as there is some long-term fallowed or native land nearby. Rangeland that is not irrigated can be particularly compatible with native wildlife. The benefits that agricultural lands provide to native wildlife are mostly different from and of lesser value than those benefits which are associated with native lands, and are usually thought to be less than what is needed to maintain viable populations. To summarize, agriculture can be a good neighbor to native wildlife, but is not necessarily a good home. The land retirement program has the potential to return large blocks of land to a native condition for use by wildlife. Land retirement is expected to primarily benefit endemic and other native upland wildlife that use natural lands.

The most obvious beneficiaries of retiring cultivated land are burrowing animals that would no longer be subject to plowing and other ground disturbing activities. Examples include the various kangaroo rats and field mice. These animals may establish a population on the fringes of agricultural lands, but these populations are heavily impacted whenever the fields are cultivated or sprayed with pesticides. The native species of the San Joaquin Valley that live in burrows or in other ways are dependant on burrows include most of our threatened and endangered vertebrate species such as the Tipton and Fresno kangaroo-rats, the San Joaquin kit fox, and the blunt-nosed leopard lizard. Other non-listed, but vital organisms for this area that are also ground dwellers include the coyote, Heerman's kangaroo-rat, side-blotched and whip-tailed lizards, burrowing owls, deer mice, grasshopper mice, and many more. The degree to which retired lands would benefit these burrowing animals would likely be dependent upon the depth of groundwater and surface microtopography.

Another suite of species that could become established on lands that are retired include many of our native and naturalized plants. The presence of native plants is essential for long-term viability of many of the native animals discussed above, and should be encouraged to become established on retired farmland. Many of these plants require undisturbed soils and a low nutrient level in the soils to out-compete many of the introduced weedy annuals that usually rapidly colonize fallow land. Vegetation management can be used to actively enhance retired land, creating conditions more conducive to the establishment of a native plant community. As retired lands become more naturalized over time, some of the endemic plant species may be able to out-compete weedy species. Reestablishment of native plant communities on retired agricultural land will benefit wildlife through increased biodiversity, in addition to increasing the cumulative amount of wildlife habitat available in the Valley.

While the creation of native communities is a desired outcome, without active management in the initial stages, retired parcels have the potential to become fallow, weedy fields. Such fields are usually recognized as a source of pests in adjoining agricultural lands, but agricultural lands can also be a source of invasive organisms for native lands. The location of a retired parcel contiguous to native land would provide some level of protection of that native habitat from

agricultural pests. A potential drawback to this is that a retired parcel could need to be actively managed for quite some time to prevent weedy communities from dominating and posing problems for both agriculture and native lands that are nearby (see the section on potential negative effects below).

Connectivity of currently isolated native lands is another benefit which could occur by retiring agricultural lands. Many remaining native areas exist in isolated parcels surrounded by agricultural or urban areas, which is not conducive for movement and dispersal of wildlife. Retired land has the potential to provide travel corridors for wildlife, essentially connecting natural areas within a farmland/urban matrix.

The ratio of native or fallow land to cultivated land that is required in any given region to support a community of native wildlife is very difficult to determine but should depend on the species considered and the type of agriculture practiced. Larger or more mobile animals tend to be able to range further from native land so that their use of farmland can occur at a greater distance from any native land. Most birds are a good example of this in that they can fly for miles to forage on agricultural lands and then return to an area that is better suited for nesting or roosting. Another example is the San Joaquin kit fox, which can forage over a mile from their den as long as some sort of protective shelter or cover is available for them to escape predators (ESRP unpubl. data). Retiring land adjacent to or near cultivated agricultural land may increase the ability of some wildlife to utilize the cultivated areas.

In summary, there are many potential benefits of land retirement for wildlife. The amount of effort expended on establishment and management of any retired land will likely be crucial in determining the final outcome. The composition of communities that could become established when land is retired from cultivation are expected to be dependent upon many factors, and a community of relatively complex diversity might not become established without assistance. The ability of the communities to maintain structure and diversity without active management might also be limited. If sufficient effort is expended to establish and maintain communities of native plants and animals on retired farmland, the ecological sciences of restoration and endangered species recovery will be furthered and other biodiversity efforts within the San Joaquin Valley will benefit.

Potential Negative Effects to Wildlife from Land Retirement

Retiring agricultural land and allowing it to become wildlife habitat should theoretically be beneficial to wildlife, but there are potential negative effects to consider. Many of these effects can be avoided or minimized with proper establishment, management, and monitoring, but some may occur regardless.

Potential negative effects to wildlife could occur from selenium exposure on retired agricultural lands. Lands identified as candidates for retirement have problems such as high water tables and high selenium levels in the soil and groundwater. Such lands often utilize a tile-drainage system which removes irrigation water from a field once crops have been irrigated. San Joaquin Valley agricultural drainage problems gained national attention with the discovery of embryo deformities and mortality in waterfowl at the Kesterson National Wildlife Refuge and other areas in the 1980's (Ohlendorf 1989, Skorupa 1998). Kesterson Reservoir had received subsurface irrigation drainage water for a number of years before impacts were noticed and studied in breeding aquatic birds (Zahm 1986), although impacts were likely occurring from the onset of flooding with drainwater.

Research on impacts to wildlife associated with selenium toxicity from agricultural drainage has focused largely on the effects on aquatic species (Ohlendorf et al. 1986, Ohlendorf et al. 1987, Ohlendorf et al. 1988b, Paveglio et al 1997). Although some work has been done on selenium levels in amphibians and reptiles (Ohlendorf et al. 1988a), birds (CH2M Hill 1998), San Joaquin kit foxes (Paveglio and Clifton 1988), and other mammals (Clark 1987, CH2M Hill 1998) at the filled Kesterson Reservoir, comparatively little is known about the impacts of elevated contaminants on upland species from areas other than Kesterson. Guidelines for background levels of selenium found in natural populations have been developed and are available for use as a standard of comparison for information collected on retired lands (USDI 1998).

Many factors can influence the availability of selenium in an upland system, including soil type and selenium levels (and oxidation state) in the soil (Abrams et al. 1990). Groundwater depth and sediment coarseness also influence the mobility of selenium in the soil profile (Zawislanski et al. 1992). Microbial activity can also influence bioavailability (Alemi et al. 1988), as well as the presence of a surface salt crust (Zawislanski et al. 1992). Plant bioaccumulation of selenium is another potential pathway for contamination that could occur on retired lands and should be carefully monitored (Abrams et al. 1990, USDI 1998). All of these variables indicate the complexity of the circumstances under which selenium can become bioavailable and toxic to wildlife. To fully understand the similarities and differences between retired land and situations like Kesterson, comparisons of contaminant concentrations in soils, vegetation, biota, surface waters, and ground waters associated with land parcels available for retirement, and of those retired, need to be made with data for Kesterson.

Currently, it is difficult to assess the potential negative impacts which may occur on retired farmland contaminated with selenium because of the relative lack of comparative research. A best-case scenario for retired drainage-poor, high-selenium soils would be no contamination of the upland habitat, and consequently no negative effects to wildlife. A worst-case scenario would occur if

contaminants in shallow groundwater are drawn to the surface through bare-soil evaporation, possibly leaching even more salts from the soil as the groundwater rises, producing persistent pools of water containing elevated salt and selenium levels.

At Kesterson Reservoir, seasonal groundwater rises occurred and were largely attributed to flooding of large acreages of nearby wetlands (Poister and Tokunaga 1992, Tokunaga and Benson 1992, Zawislanski et al. 1992). Although flooding of large areas near retired lands is not an expected scenario, inflow of irrigated drainwater from up-slope irrigated fields could pose a problem on retired lands if it were to cause the groundwater to rise to the soil surface and form pools of contaminated water (Tanji et al. 1986, Tokunaga and Benson 1992).

Ephemeral pools which formed seasonally at the filled Kesterson Reservoir were surveyed from 1992-1997 and highly elevated levels of selenium were detected in both the water and resident invertebrates (CH2MHill 1998). These pools were formed as a result of shallow groundwater rise through bare-soil evaporation and the interaction between the groundwater and surface soil conditions (Deverel and Fujii 1988, Tokunaga and Benson 1992, Zawislanski et al. 1992). Kesterson soils that were flooded with drainwater tended to accumulate reduced forms of selenium in pond sediments that were later reoxidized into mobile forms as the system dried out (Alemi et al. 1988, Poister and Tokunaga 1992, Tokunaga and Benson 1992, Tokunaga et al. 1996, Zawislanski et al. 1992, Zawislanski and Zavarin 1996). Oxidized forms are more bioavailable than reduced forms of selenium (Tokunaga et al. 1996), and influence the amount of exposure to wildlife in pooled water at Kesterson.

While small pools are likely to form during the rainy season on retired lands, and some of these may contain elevated levels of contaminants, it is premature to assume these pools will be highly toxic to wildlife. While groundwater conditions between Kesterson and potential retired lands are similar due to the selection criteria for land retirement which includes high water tables with elevated selenium (USDI 1997), soil conditions will likely be dissimilar. Since each of these factors influences the bioavailability and toxicity of associated surface pools, outcomes will be different on each parcel of land. Monitoring of contaminant levels in the seasonal ephemeral pools and associated wildlife on retired lands is essential to identifying negative impacts.

Past and current monitoring at Kesterson clearly indicate a need for caution and close monitoring of retired land, on a site-by-site basis. However, direct comparisons between retired lands and Kesterson, past and present, are problematic, because of numerous differences between the two situations. Retired land will be managed as upland habitat, not as wetland habitat. The aquatic food chain was identified as the pathway for contamination at Kesterson (Presser and Ohlendorf 1987), and efforts to decrease selenium exposure have focused on decreasing the availability of contaminated food sources to affected

wildlife, including filling in all wetland areas with soil to form an upland community (Zahm 1986). Research regarding the distribution and biomagnification of selenium in filled areas at Kesterson have found that while bioaccumulation has been occurring in the upland grassland, it has occurred at less than 10% of values measured at Kesterson when it served as a wetland (Wu, et al. 1995). While this research is intriguing, the study was conducted during drought years, and may or may not represent the dynamics of selenium in high rainfall years.

Another difference between Kesterson and retired agricultural lands relates to the condition of the soil at the time of restoration. As noted above, the sediments beneath filled areas at Kesterson were saturated with agricultural drainwater for years prior to closure, leaving high concentrations of salt and selenium at the soil surface (Tokunaga and Benson 1992, Zawislanski et al. 1992). Prior to the halting of discharge into Kesterson, most of the inflow between 1981 and 1985 was almost exclusively subsurface agricultural drainwater (CH2MHill 1992). Retired lands will never receive agricultural drainwater for impounding or evaporation. In fact, many areas purchased for retirement will have tile-drains present for leaching of salts which can decrease the amount of available selenium (Fujii et al 1988).

The filling and grading of Kesterson Reservoir, ordered by the State of California in 1985 (Order No. 85-01), effectively eliminated the toxic aquatic situation and provided an opportunity to monitor selenium contamination in a modified upland environment. Monitoring has shown elevated levels of selenium in terrestrial species at Kesterson, but teratogenic and reproductive effects have not yet been found (CH2M Hill 1995, 1996, 1998). Nevertheless, close monitoring of retired parcels and careful selection of lands for restoration is essential.

The redistribution of water from retired lands also pose threats to wildlife. Water originally applied to retired lands will be available for use elsewhere. If this water is applied to lands adjacent to retired parcels, the potential for accumulation of contaminants on the retired parcels may increase, potentially exceeding safe ecotoxicological thresholds for wildlife. There is also the potential for this water to be redistributed to areas that have not been previously cultivated, resulting in a net loss of wildlife habitat. Care must be taken to avoid these scenarios.

Other potential negative effects from land retirement may arise from a lack of monitoring or management which could lead to the development of undesirable plant communities. While an increase in available habitat through land retirement would be a great benefit to wildlife, without proper management the retired land could become densely vegetated with non-native grasses and exotic species. Burrowing animals need open areas to travel for foraging and reproduction; densely vegetated fields may preclude the establishment and

survival of small mammals and other vertebrates. In such a situation, retired land would provide little wildlife habitat value.

Another potentially harmful consequence of allowing weedy communities to develop on retired land is related to public perception. Operators of agricultural lands adjoining retired land that becomes a weedy nuisance would likely be opposed to any new restoration activities including any that could potentially take place on their own lands (along canal banks and between fields, for instance). Adaptive management of retired lands is the best way to prevent the establishment of weedy communities. Through proper monitoring and feedback into ongoing maintenance activities, plant species that are hosts to beneficial insects and other predators can be selected and encouraged to thrive. Although just about any community will have pest species, if management is ongoing and properly applied, the beneficial organisms may dominate.

Considerations for Maximizing Biological Benefits

Many factors must be considered when maximizing the potential benefits of retired lands to wildlife. Some factors of great importance include:

1. The length of time that would be required for restoration of a plant community and wildlife to become established,
2. The habitat types and habitat quality that would ultimately develop (which would be determined, in part, by site-specific soil and hydrological conditions),
3. The size and locations of retired parcels, and
4. The length of time that the parcels would be out of agricultural production.

Because the lands being considered for retirement have been surface-leveled, irrigated, furrowed, and cultivated, some conditions may exist that would prohibit their natural revegetation. Repeated cultivation has been shown to eliminate sources of native seed in the soil. The application of herbicides, pesticides, and fertilizers on the cultivated lands may also prohibit natural revegetation. It is therefore expected that up to 20 years or more could be required for suitable habitat and populations of wildlife to develop on retired parcels without assistance. An approach that would have a greater probability of success and a substantially shorter period of recovery would be to actively enhance retired lands. This could be accomplished by numerous techniques, depending upon conditions and recovery goals on each site. Appropriate techniques may include planting plugs, seeding, and transplanting appropriate species of plants, eliminating competing plant species, creating micro-relief, creating artificial burrows, and importing wildlife.

Habitat types and habitat quality also would affect suitability for wildlife. A mosaic of habitats would be more beneficial to wildlife than any type of monoculture, as would topographic relief and the elimination or reduction of undesirable plant species. The site-specific soils and hydrologic conditions would ultimately influence the type and quality of habitat that develops on a site, in addition to the level of management. Site conditions that favor agricultural production are often at odds with conditions that favor the types of plant communities that historically occurred in the project area. The past use of fertilizers and other soils amendments in conjunction with deep ripping and leveling may combine to produce a very weedy situation that would not result in desirable wildlife habitat. But, this situation would not be expected with great frequency on the lands considered for retirement because of their generally low productivity, high water table, and highly saline condition. A mosaic of habitat types and a variation in plant density, species composition, and a generous amount of bare ground would be desirable habitat characteristics. Active

management, especially during the initial stages of habitat restoration, would help assure high quality habitat development.

Except in special circumstances, small isolated parcels are of little value to wildlife. Primarily this is because of edge effect, which generally reduces habitat quality, and increases isolation, which limits the long-term viability of wildlife populations (Kelly and Rotenberry 1993). Large acreages of land, strategically located and providing a mosaic of habitat types and a high abundance and diversity of wildlife, would be of superior value. Parcel sizes of 5,000 acres and greater would be required to provide stable populations of many wildlife species.

Special circumstances occur when many small parcels, strategically located, can provide connecting corridors between other larger parcels containing viable populations.

The benefits of land retirement to wildlife would be minimal if long-term retirement is not practiced. Real benefits to wildlife would not be realized unless land was retired for 50 years or greater; retirement “in perpetuity” would be preferable.

Conclusions and Recommendations

Many benefits to wildlife are possible through the land retirement program. An increase in the amount of wildlife habitat, and the connectivity between natural land parcels, should substantially enhance wildlife resources in the San Joaquin Valley. Reductions in the volume of agricultural drainwater and selenium concentration in the drainwater which should occur as a result of land retirement should also benefit Valley wildlife, particularly aquatic species. The restoration of native plant and animal communities on retired land may increase biodiversity, and will provide important habitat for both endangered and non-endangered Valley wildlife.

Negative effects from land retirement are also possible, including selenium impacts and the potential for establishment of undesirable weedy plant communities, but given the lack of available information regarding the land retirement process, any conclusions at this point regarding negative impacts are premature. Comparisons of contaminant concentrations in soils, vegetation, biota, surface waters, and ground waters associated with land parcels available for retirement, and of those retired, will be made with Kesterson Reservoir.

One of the ecological goals of land retirement is meaningful restoration of wildlife habitat on retired agricultural lands. Creation of a contamination hazard on retired lands is in conflict with this goal and is not an expected outcome. Trigger mechanisms should be in place for contamination contingencies which, when observed, will set into motion appropriate managerial action. Any indication that contamination is occurring on retired lands will lead to immediate steps to remediate the effects.

Each retired parcel will be different, and hence different outcomes may occur on each piece of land. In order to best establish and maintain any particular parcel, a site-specific habitat management plan should be developed which explicitly states the goals and objectives for that parcel. Each management plan should be based on the adaptive management concept (Holling 1978) to take advantage of changing situations in the field, and should include protocols which address specific revegetation and monitoring needs. The continued type and degree of management of a parcel should be dependent on the results of the monitoring. Monitoring tasks for each parcel should include measurement of selenium levels in soil, ground and surface water, vegetation, and animals. Groundwater levels should also be closely monitored to determine the effects of retirement on retired and nearby lands.

It would be a prudent step to test management strategies on a small scale prior to implementation of expensive and labor-intensive practices on large areas of land. Appropriate test plots might range from a few hundred to a few thousand acres. With this approach, methods to promote habitat restoration can be explored and manipulated in a scientifically valid manner with control and experimental plots. Results can then be used to prepare adaptive management plans for specific parcels.

Monitoring of the disposition of freed-up water available from land retirement is needed as well as an analysis its potential usefulness in meeting the needs of habitat restoration and wildlife protection. It is hoped that some restored habitat would ultimately be suitable for endangered, threatened, or other sensitive species, and would be managed as reserves for those species. In fact, the recovery plan for upland species of the San Joaquin Valley (USFWS 1998) identifies land retirement as instrumental in the recovery of many endangered, threatened, and sensitive species.

C. PEDOLOGIC CONSEQUENCES OF LAND RETIREMENT AND RELATED ISSUES

Potential for Soil Salinization Following Land Retirement

The SJVDP 1990 Plan in evaluating options states on page 92 that: *... virtually all options have some limitations or produce an adverse effect on an important parameter of interest: for example, fish and wildlife, the economy, or the local community. Conversely, each option shows characteristics and*

effects beneficial to some interests. Judgment has to be exercised in determining the emphasis to place on a given option, considering the balance of effects. The lowest-net-cost option is sought but not at the expense of significant risk to other interests.

In Tables 17, the SJVDP recognized that land retirement is simple from engineering point of view, but may require some decommissioning of facilities; has impacts on local communities, but may require institutional arrangements; eliminates any on-site hazards assuming alternate land use and management are not a problem; takes land out of production perhaps permanently, but frees up water that could be reallocated to agriculture; and frees up water for fish and wildlife use, but the reuse of retired land for wildlife is unproven.

Hydrologic investigations by the SJVDP indicated that if substantial areas of land were retired, the shallow water table beneath those lands would drop up to 20 feet in 10-15 years. The SJVDP recognized that the feasibility of land retirement hinges on the existence of shallow-water-table-areas in which concentrations of selenium are much higher than those of surrounding areas (see Introduction).

The SJVDP estimated abandonment of up to 460,000 acres of lands due to drainage problems including soil degradation by salinization by the year 2040 (SJVDP, 1990, Tables 11 and 45). The land retirement option as presented by the SJVDP and the CVPIA is intended to enable agricultural production to continue at present levels in the future by reducing amounts of "problem water" and "problem acreage" (SJVDP, 1990, Table 46). This outcome is not without some expense in converting lands to other uses and managing soil and land resources to minimize adverse effects. The potential effect of the implementation of land retirement upon soils or the pedologic consequences of taking irrigated land out of production in arid climates involves consideration of:

- the fate of the salts present in the soil profile at the time of land retirement;
- the upward transport of salts from groundwater through the vadose zone to the soils surface following land retirement where groundwater is closer than 10-20 feet to the soil surface;
- the suitability of retired lands for other uses, i.e., alternate land uses including dry-land farming and wildlife habitat; and
- the management of the potential hazard of airborne salts and dispersal of such toxic elements as selenium.

The 1990 Management Plan was a good first attempt, using information available at the time, to address the drainage problem using several in-valley management actions such as land retirement, water-use efficiency, source control, drainage reuse, and groundwater management. Modeling efforts subsequent to the SJVDP suggest that the soils of retired lands could in time become salinized and unsuitable for sustained agricultural or upland wildlife habitat uses. However, the upward transport of salts from groundwater through the vadose zone to the soil surface following land retirement where groundwater is closer than 10-20 feet to the soil surface was not studied by SJVDP. Likewise, no studies were done to evaluate the fate of the salts present in the soil profile at the time of land retirement. No detailed studies were conducted on the suitability of the retired lands for other uses. No detailed studies were conducted on the environmental consequences of various land retirement scenarios. SJVDP made an assumption that alternate land uses and its management would not be a problem.

A preliminary evaluation of potential soil salinization of retired irrigated lands in the western San Joaquin Valley, conducted at the USDA Salinity laboratory for the purposes of this report, is presented below based mainly on field observations and model calculations of water and salt transport in unsaturated soils. A set of conditions is presented under which salinization of soils may occur to the extent that it may limit use of the land as wildlife habitat or for dry-land farming and present a hazard due to airborne salts. Selenium is treated as a component of the modeled salt.

The authors of the modeling study at the Salinity Lab proposed a number of alternatives to achieve the purposes of the 1990 Plan land retirement. These alternatives could meet the objectives of reduced pollution from drainage and water conservation, while minimizing, or avoiding altogether, the degradation of soil and reduced capacity for plant growth that will likely result with the recommended plan.

Reasons for Suspecting Soil Salinization Problems in Retired Lands

Fields underlain with shallow (3-10 feet, depending upon various soil and climatic factors), saline ground waters (especially when surrounded by irrigated land) will, when left fallow, eventually accumulate salts in the surface soil layer. The salts that accumulate at the soil surface derive from those present in the rootzone and in the shallow groundwater; they are transported to the soil-surface by unsaturated flow-processes that are driven by the evaporation of water. A standard recommendation for soil salinity control is to avoid, or minimize, periods of fallow when either the soils are saline or saline ground waters exist at relatively shallow depths. However, in Pakistan, a common practice is to intentionally leave fields fallow for extended periods of time under such conditions in order to “concentrate” and deposit salts at the soil surface, so they can be physically collected and removed from the field. While this practice is not recommended or

very effective for very long, it does illustrate the degree to which salts within the profile can move to the soil surface under non-irrigated, saline and waterlogged conditions.

The retirement of blocks of land surrounded by irrigated fields, as envisioned in the present land-retirement strategy, is analogous to long-term “fallowing”. In fact, the “Rainbow Report” recognized that the retired land may act as a sink to collect drainage-flows and salt from the surrounding areas. The essential differences between fallowing and land retirement are the size of retired blocks of land in relation to the surrounding irrigated area and the duration. The water table recedes when large areas of land are retired and the rate of transport of salt up into the surface soil is reduced relative to fallowing, but the overall magnitude of the transport may be greater because the time period over which the “subbing” process operates is so much longer than it is with fallowing. Thus, a large block of retired land will accumulate salts at a slower rate, but may, in the long run, accumulate much more salt per unit area than will an individual fallowed field.

Fields “whitened” with surface deposits of salts formed by the cessation of irrigation are commonly observed around the world, including the San Joaquin Valley. An example may be seen in a block of fields located south of Hanford near the intersection of 19th and Kansas streets. During wind-storms, surface salt could be “picked up” and added to the airborne sediment load that “clouds” such fields and the adjacent area downwind. This “pick up” is enhanced by the absence of ground cover. The salt-load in the wind-borne pollution is another potential hazard associated with the accumulation of surface deposits of salt. An example of an area with a severe problem of this type is the Owens Valley. Selenium would be expected to be a component of these surface accumulations of salt. Thus, a possible outcome of land retirement intended to minimize the contamination of surface waters could be the contamination of soils and other parts of the environment if left unmanaged.

The growth of most plant species is limited by the presence of surface accumulations of salt, so one may expect that habitat available for wildlife and grazing will be reduced by land retirement. It should be recognized that whatever habitat may develop on the saline, poorly drained lands upon their retirement may be different than that originally present there prior to irrigation. This is so because the hydrological processes in the Westside irrigation region have mobilized salts within the deeper geologic sediments, redistributed and localized them into the trough region, which prior to irrigation had a deeper ground water depth and was frequently submerged by fresh water floods. The suitability of salinized soils for dryland crop and rangeland production will be discussed later; its suitability for wildlife habitat is discussed in Section D.2 of this report.

Theoretical Processes of Water Flow and Salt Transport in Unsaturated Soils

The mathematics describing the flow of water and transport of salt from a water table and through the soil is complicated and will not be described herein. A lucid description of these processes, along with useful schematics, has been prepared by van der Molen (1976). Gardner (1960) and van Schilfgaarde (1976) give excellent descriptions of the processes and atmospheric and soil properties which control “capillary rise/flow” and the accumulation of salts in non-irrigated soils. A qualitative description to judge whether salinization is likely to occur, or not, upon the retirement of lands specified in the “RRLRP” will be given herein.

As a first approximation, soluble salts may be envisioned as being carried along with the flow of soil water and in groundwater currents, although there are cases where soluble salts and water do not travel together, or at least not at the same velocity. The most obvious case is evaporation where water is lost to the atmosphere, but the salts remain behind. Salts, therefore, tend to concentrate in places where water flows and evaporates. In the case of land retirement, that place will be the topsoil of the retired field and below the surface if native or introduced plants remove water via their roots. Another less obvious case of salt movement is diffusion in which salts are driven to move from where their concentration is high to where it is low. The composition of the salts is influenced by ion adsorption and cation-exchange reactions, which occur during transport, and by salt precipitation during concentration. Salts, therefore, are transported from places where water is entering the rootzone towards where it evaporates. They accumulate in places where groundwater rises close to the surface and where evaporation takes place. As noted by van der Molen, the seepage of water and salts from irrigated fields to adjoining dry fields is a common process. Under irrigation, water tends to move downward and salinization is curtailed, but under fallowing (and under retirement) water moves upward and evaporates, so that salts accumulate, often to very high levels. Seepage currents are rarely strong such that the groundwater reaches the surface. Usually, an unsaturated zone remains present, through which water rises by “capillary action” towards the soil surface. Capillary rise will lead to a lowering of the groundwater table. This, in turn, will cause a decrease in the rate of upward flow and finally the process will come to a standstill, if neutral groundwater conditions exist (i.e., if neither natural drainage nor seepage occur). If groundwater is flowing into the retired land area from adjacent upslope irrigated fields, the groundwater will be maintained at a higher level under the fallowed land. If the amount of salt transported by this process is large it may lead to severe salinization. Therefore, it is especially important to know the extent of upslope seepage (Section D.2), in order to predict the degree to which salinization will occur with fallowing (land retirement). Thus, it may be necessary to provide drainage for the retired land even when irrigation is eliminated (van der Molen, 1976).

The concept of the so-called “critical water table depth” (Section D.2) is often applied (as are depth-criteria, RR) to predict whether a soil will salinize in the presence of a saline groundwater. It has led to estimates for critical depths varying from 1 to over 3 meters, depending on soil texture, soil morphology, climate (including rainfall), quality of the groundwater, cropping patterns and

other factors. Calculations of acceptable depths are usually based on the assumption that the upward flux does not exceed 1 mm/day for irrigated soils. But, as van Schilfgaarde (1976) has shown over time any net upward rate will salinize a soil. Excessive accumulation of salts can be prevented by maintaining a net downward flux of water sufficient to overcome the upward transport. Even with a shallow groundwater depth, upward flow will only occur when there is an upward gradient. In some cases, the shallow groundwater caused seepage (lateral inflow) from surrounding areas due to natural causes or by excessive irrigation upstream. Likewise, artesian pressures can occur in semi-confined substrata beneath lands; the recharge can be occurring at “far” distances away, yet cause a slow but continuous upward flow into the lower-lying area. A possible solution to this problem is a set of rather widely spaced wells, pumped at a rate just sufficient to reverse the hydraulic gradient (van Schilfgaarde, 1976).

The upward flow from the soil to the atmosphere is initially limited by the rate of evaporation, which is controlled by atmospheric conditions (temperature, relative humidity, wind speed, etc.). However, when the soil dries below an equivalent value of 1 or 2 bars of “suction”, the rate of upward flow becomes limited by the hydraulic properties of the soil. Some data showing the “transmitting” rates of different soils are given in Kruse et al. (1990) and in Hanson et al. (1993, page 58). For clay loam soils like those present in the areas designated for land retirement, the rate of upward flow becomes limited by soil transmission properties when the water table falls below about 5 feet (Hanson et al., 1993). The upward movement of water and thus salt is constrained by the soil's limited ability to conduct water under very dry conditions at the surface. This is the expected condition during the summer months when the evaporative demand is the greatest.

A word of caution is in order, however. If the conductivity is sufficiently high the rate may be sufficient to present a salinity hazard when the groundwater is saline, even though the water table may be several meters below the soil surface (Gardner, 1960). As long as the suction at the soil surface in centimeters is greater than the depth to the water table, water will move upward. Experimental studies have shown that water can certainly move from water tables at least as deep as 7 meters at appreciable rates (Gardner and Fireman, 1957) if the hydraulic conductivity is large enough. According to the latter authors, “upward movement and evaporation of water is possible with the water table as deep as 25, 30, or more feet, and, although the rate will be slow, accumulation of harmful amounts of soluble salts is possible if the groundwater is saline and if sufficient time is allowed”. Obviously, this phenomenon requires a dry soil and will not prevail under high rainfall conditions; but it will in retired lands if the yearly ET exceeds the yearly rainfall and water application, which may occur in the Westside area of the San Joaquin Valley.

Salts present in the soil profile at the time of “retirement will also be redistributed to the soil surface following the cessation of irrigation, so long as the

net ET exceeds the net rainfall and water application. This can even occur in irrigated soils, as shown by the experimental data of Hanson et al. (1993; see pages 42 & 45) and Rhoades, et al. (1997).

Estimates of Soil Salinization Resulting From Land Retirement

Estimates of the levels of salts that will develop in retired lands were made by three means, in order to evaluate the likelihood and degree of this problem. The author (J. Rhoades) made simple calculations to scale the magnitude of the potential problem. Todd Skaggs and Don Suarez (both at the U. S. Salinity Laboratory) undertook modeling calculations to evaluate the influence of groundwater depth and soil hydraulic properties on the rate of salinization and the effects of salt precipitation, salt-diffusion and initial level of soil salinity on the resulting level of salinity. In all three estimates, it was assumed that the downward drainage following retirement was countered by lateral inflows so that the water table depth was static; rainfall was ignored because it is less than ET (but the rate of salinization would be reduced by rainfall). The effect of rainfall should be considered in the future modeling studies that are recommended later.

Since downward flow is assumed to counter lateral inflow, rainfall, which is about 6-15% of total ET, is ignored, and the assumed water content of the soil surface is much higher than expected during the dry summer months, the results border on a worst case scenario for soil salinization.

Estimates Based on Salt Balance

As mentioned earlier, when the water table is “deep”, the rate of upward flow is limited by soil properties, primarily to texture and morphology (Gardner and Fireman, 1958). The evaporation rate of Chino clay determined by the latter investigators for a water table depth of 6 feet was about 1 mm/day (see figure 5 in their paper). Approximate upward flux for a range of soils and water table depths are given in Kruse et al. (1990); the rates for clay loam and silty clay loam soils like those present in the proposed land retirement areas are about 2.0-2.5 mm/day for the condition of a water table at a static depth of 2 meters. Their corresponding rates for a water table depth of 1.5 meters (~ 5 feet) range between about 5.0-8.0 mm/day. With the simple, reasonable assumption that the upward flowing water carries all of the salt with it, it can be shown that a rate of just 0.5 mm/day of upward flow (the rate could be higher or lower for the different types of soil found in the proposed retirement areas) from a groundwater having a salinity equivalent to 10 dS/m (~ 8.7 ton per acre-foot; typical of the groundwaters in the proposed land retirement areas) will, in time, deposit about 5.2 tons of salt at the soil surface per acre per year $[(0.5 \text{ mm per day} \times 365 \text{ days}) / 25.4 \text{ mm per inch} / 12 \text{ inch per foot}](8.7 \text{ t.a.f.})$; the rate of salt-loading would be proportionately higher if the rate of upward flow exceeds 0.5 mm/day]. This amount of salt is equivalent to about 0.5 % of the soil weight (dry basis). Ignoring any “back-flux” of salt from the topsoil due to the influence of salt-diffusion or rainfall, this amount of salt would increase the E_{Ce} in the topsoil (0-6

inch depth) by about 14 units (dS/m) per year (see figure 7, U. S. Salinity Laboratory Staff, 1954). An ECe of about 20 dS/m is considered the highest level of salinity that a crop-plant can survive under in an irrigated soil. At such a level of salinity, cotton (one of the more salt-tolerant crops) yield would only be about 10 % of potential yield. This simple estimate shows that the potential for salt to be transported from the groundwater and to be deposited at the surface of retired lands during the period of just a single year (once the wetting front arrives there) is substantial. The minimum time it would take before any salt from the groundwater at a depth of 6 feet would reach the topsoil may be roughly estimated, ignoring rainfall, as about 10 years ($0.5 \text{ mm/day} = 0.6 \text{ feet per year}$).

The effects of rainfall deserve to be evaluated, but the relative sparse winter rainfall (~ 6 inches; of which about 1/3 to 1/2 is effective) is not sufficient to prevent the accumulation of salts in the soils given the overall prevailing high evaporative conditions (yearly class pan evaporation of about 95 inches). The rain would simply temporarily leach some of the salt from the surface down a little in the profile. With a very dry soil existing at the time of rainfall, the moisture content of the soil would not be expected to increase enough to significantly affect the average hydraulic properties of the soil (the soils would actually transmit more water to the surface if they were wetter). The most likely overall effect of rainfall would be to slightly spread the layer of salt accumulation down a few inches in the topsoil.

The water flowing upward from the soil profile and from the groundwater would also transport the salt initially present within it; i.e., the salt already present within the soil above the groundwater would be redistributed to the near-surface depth adding another “one-time” contribution to the surface salinity. Ignoring “back-diffusion” and rainfall, this can be estimated to be about 36 tons per acre in total for a typical soil whose average salinity is 8 dS/m (~0.3 % dry soil basis and typical of the saline lands proposed for retirement) over the 0-6 feet depth. Assuming this salt is accumulated within the 0-6 inch depth, the salinity concentration in the saturation-extract would be additionally increased after a period of about 10 years by about 96 dS/m (8×12 ; assuming all of the accumulated salt dissolves in the extract). This level alone is so high that essentially no crop plant, or hardly any halophyte, could grow. Of course, some limited growth could occur during the first few years of the ten-year span before all of the salt has been accumulated; the total 36 tons can be assumed to be accumulating at a linear-rate of about 3.6 tons per year (the equivalent yearly increase in ECe would be about 10 dS/m). Thus, the groundwater need not even itself be saline to cause a retired soil to become excessively saline in time following land retirement; there is already enough salt in the soil to become limiting for any practical plant growth, when redistributed and concentrated in the topsoil. While these results have been expressed in terms of salinity, individual solutes, such as selenium, will be redistributed and concentrated by the same process. Thus, if selenium is present as selenate (the mobile species found in typical soils and groundwaters) at a average concentration of 50 ppb in the soil

water, it will become 600 ppb (50×12) in the water within the topsoil if selenium undergoes no transformation; of course, this level will be increased as selenate is transported into the topsoil from the groundwater. Obviously, the potential for selenium poisoning will be great at such levels, if forage plants were able to grow under such highly saline conditions.

Another source of salts that will be transported to the topsoil upon retirement are those present in the volume of water that occupied the saturated pore space (plus that in the associated “capillary fringe”) before retirement when the groundwater was at a shallower depth compared to afterwards. For example, if the water table was at 4 feet before retirement and was lowered to a depth of 6 feet by the “subbing” of water to the surface, a volume of water equivalent to that depleted from 2 feet of previously saturated soil, along with the dissolved salt in it, would also flow into the topsoil (assuming no drainage outflow) upon retirement. Assuming the saturated porosity to be 0.4 volumetric in the soil depth 4-6 feet before retirement and to be 0.25 feet after retirement, the salt transported to the topsoil would be about 2.6 tons per acre $\{(0.45-0.25 \text{ volumetric water content})(2 \text{ feet}) (8.7 \text{ t.a.f.})\}$.

The total salt transported into the topsoil from the three sources as estimated above would be as follows. Assuming a groundwater decrease from 4 feet before retirement to 6 feet following retirement induced by the upward flow of water, there would be a one-time addition of about 36 tons per acre derived from the salt initially present in the soil depth 0-6 feet; there would be another one-time addition of about 2.6 tons per year derived from the salt initially present in the groundwater contained within the 4-6 foot depth of soil, and there would be an annual addition of about 5.2 tons per acre (assuming a steady-state upflux rate of 0.5 mm/day) derived from the groundwater remaining at 6 feet. After a time period of about 10 years, the salinity would progressively increase from its assumed preexisting salinity level of about 8 dS/m (saturation extract basis) to about 122 dS/m by the addition of about 44 tons per acre (the 122 dS/m total increase consisting of about 100 units from the 36 tons, 8 units from the 2.6 tons and 14 units from the 5.2 tons). This level would increase thereafter at a rate of about 14 dS/m per year derived from the addition of 5.2 tons per acre flowing in from the groundwater. The concentration of accumulated salt is so high that some will precipitate from solution to form deposits of salt crystals, which will be subject to transport by wind to other downwind locations.

Estimates Based on Steady-State Groundwater Flow

The estimates of the increases in concentration of salts in soil water occurring throughout the soil profile (from the groundwater to the soil surface) based on calculations of the upflux of groundwater were provided by Todd Skaggs. These steady-state calculations ignore the transport of salts preexisting in a shallower water table at the time irrigation was terminated, because the groundwater depth was assumed fixed in time. Also ignored in these calculations

were the effects of rainfall, salt-diffusion and salt-precipitation. Relative increases in the concentration of the soil water, compared to the groundwater, were calculated for time periods of 1, 5, 10, 25 and 50 years of land retirement. The initial salt concentration in the soil profile was assumed to decrease linearly from the groundwater concentration at the water table to one-tenth of the groundwater concentration at the soil surface; thus, the soil was assumed to be relatively low in salinity at the time irrigation was terminated. Calculations were made for different combinations of groundwater depth (91, 137 and 183 cm.), soil hydraulic conductivity (0.5, 5 and 15 cm/day) and soil water retention properties (clay loam and silty clay loam soil types). The results show that the salt-loading rates are very dependent on soil hydraulic properties and groundwater depth. According to these results, assuming no salt initially present in the soil and no loss of salt by precipitation, the surface soil water concentration would be about 20 times that of the groundwater after 50-years of retirement for the situation where the steady-state water table depth is 6 feet, the saturated hydraulic conductivity is 0.5 cm per day, and the soil is a clay loam type. With a water table of 3 feet, a saturated hydraulic conductivity of 15 cm/day and silty clay loam soil type, the concentration at the soil surface (assuming no salt initially present in the soil and no loss of salt by precipitation) would be more than 1000 times that of the groundwater in only one year and more than 100,000 times as concentrated in 50 years. Obviously, most of this salt would precipitate out of solution and be deposited on the soil surface, since an EC of 10,000 or 1,000,000 dS/m, is extreme (seawater salinity is about 45 dS/M).

The majority of the intermediate scenarios modeled by Todd Skaggs show that salt accumulation from the groundwater will be significant. As an example, for the situation of a 6 feet deep water table and a silty clay loam soil type ($K_s = 5$ cm/day), the salt concentration at the soil surface will be about 200 times that of the groundwater 10 years after retirement; it will be about 10 times as concentrated at a depth of 5 cm. Thus, the average of the 0-6 inch depth would increase by an amount that is not very different than the EC value of 28 (the EC in terms of soil water is no less than about 2×14 dS/m in E_{Ce} units) that was estimated earlier by simple salt-balance methods. Though rainfall was ignored, it should not appreciably alter things for the reasons given earlier.

Estimates Based on UNSATCHEM Model Calculations

The estimates of the increases in concentration of soil water occurring throughout the soil profile from the groundwater to the soil surface based on his calculations of the upflux of groundwater and the chemistry reactions, including diffusion, made using the UNSATCHEM model (Suarez and Simunek, 1997) for a few of the scenarios were provided by Don Suarez. These estimates were made assuming no rainfall, the initial salt content of the soil were at intermediate levels (an E_{Ce} equivalent of about 4 dS/m) and the groundwater had an EC of about 8 dS/M with a composition very representative of existing in the proposed

land retirement areas. These simulations did not include the transport of water and salt that occur when the water table is higher at the time of retirement; the groundwater depth as assumed constant over time. Likewise, the water content was assumed to be drier than that which would probably exist at the time irrigation was terminated. Thus, the rate of salt-transport estimated by Suarez would be somewhat lower than would be expected if transient state conditions were used in which the water content would be, at least initially, higher.

The results show that with a groundwater fixed at a depth of 2 meters, the EC of the surface soil water would become, after a period of 10 years, about 35 or 240 dS/m, (the E_{Ce} would be lower by at least one-half) for soils with saturated hydraulic conductivities of 5 and 15 cm/day, respectively. The corresponding sodium adsorption ratio (a measure of exchangeable sodium) values would be about 30 and 120; sulfate concentrations would not increase above values of about 60 meq/l, because of the precipitation of gypsum, and chloride concentrations would reach values of 350 and 2700 meq/l, respectively. All of these “salinity” increases would come about simply by the redistribution and concentration of salt initially present within the soil profile, since the very low “tracer concentration” result shows that the upward flux of groundwater is just beginning to reach the soil surface at this time (after 10 years). The salinity results are similar to those obtained by the salt balance method. Results for longer periods of time were not made because the salt concentrations became so high that they couldn’t be calculated with the chemistry routines contained in the model. The model would have to be modified to include super-saline chemistry relations to do this. The results support the earlier conclusion that excessive salinization and sodification of retired lands will likely occur within a span of about 10 or 20 years, depending upon soil characteristics and groundwater depth.

The rate of salt-loading estimated by the three methods are in good agreement. All show that retired lands with saline groundwaters present within depths of about 6 feet will likely become highly salinized within a period of about 10 years. The same outcome will occur with water tables at deeper depths, though the rate of salt-loading will be slower. There will be enough salt within the soil profile at the time of retirement to salinize the topsoil of retired lands (having presently proposed conditions), even in the absence of any contributions from the groundwater.

Suitability of Retired Lands for Dryland Agriculture

The effects of salts on soil properties and plant growth have been reviewed by Rhoades (1989). Salts exert both general and specific effects on plant processes which directly influence growth; additionally, salts can affect certain soil physicochemical properties which may render the soil unsuitable as a medium for plant growth.

Effects of Salts on Soils

The suitability of soils for plant growth depends strongly on their readiness to conduct water and air (permeability) and on their structural friability (tilth). Saline soils contain excessive amounts of soluble salts for normal plant growth; however, the high content of soluble salts favors permeability and aggregation. On the other hand, sodic soils, which contain excessive proportions of sodium salts and have high pH values, have the propensity to become impermeable, compacted and crusted, when salinity is relatively low. As predicted by the model calculations of Suarez presented earlier, the sodicity levels of typical saline/sodic soils will, when retired from irrigation, become very high, as will salinity, boron, selenium, etc. As long as the salinity remains high, the predicted build-up of surface salts should not of themselves be expected to have any detrimental effects on soil permeability and aggregation; however, in the absence of crop cover and yearly additions of crop residue, the surface soil would become increasingly subject to degradation by wind erosion. The problems/hazards associated of wind erosion could be substantial.

Effects of Salts on Plants

Excess salinity within the plant rootzone, especially in the topsoil, has a generally deleterious effect on plant growth. This effect is primarily related to total electrolyte concentration, which severely restricts the seeds ability to imbibe water from the soil needed for germination and the plants ability to extract water from the soil needed for evapotranspiration. Growth suppression is initiated at some threshold value of soil salinity, which varies with crop type, stage of growth and various climatic factors which influence the plants need for water, the water-supplying potential of the soil within the rootzone, and increases as salinity increases until the plant succumbs. The most salt-tolerant of agricultural plants can not survive at salinity in excess of about 20 dS/m. As discussed above, salinity levels higher than this, even exceeding 100 dS/m, could be expected to occur in the topsoil of proposed lands upon retirement. Even halophytes will not grow under such latter conditions (Aronson, 1989; Miyamoto, 1996). The harmful effects of salinity have been mostly quantified under conditions of irrigation. They can be expected to be magnified under dryland conditions where the exposure of the plant to water stress will be higher than under irrigated conditions.

While the primary effect of soil salinity is one of retarding growth, as discussed above, certain salt constituents are specifically toxic to some plants. Boron is such an element and is prevalent in the proposed land retirement area. It is highly toxic to most plants when present in the soil solution at concentrations above about 10 ppm (Maas, 1990). Boron concentrations of 5-10 ppm are typically found in the groundwaters underlying the proposed retirement lands. Obviously, the potential for boron toxicity could be substantial

if, upon retirement, the concentrations in the topsoil eventually reach the predicted levels, which are higher by a thousand-fold or more. Boron toxicity was observed in the eucalyptus drainage water-reuse study undertaken in the “Westside problem area” by Tanji and Karajeh (1992), even though the boron concentrations were far less than those predicted to occur with the proposed land retirement. For some woody crops, sodium and chloride may similarly accumulate in the plant tissue over time to toxic levels that produce foliar burn and then death. Tolerance levels for such elements and woody crops are also given in Maas (1990). Sodic conditions like those predicted to occur upon retiring land may also induce calcium, as well as other nutrient, deficiencies, but these have not been well studied under such extreme conditions of salinity as those predicted to occur with land retirement.

Effects of Salts on Foods and Forage Quality

Salts can accumulate in some plants to such levels that their food quality is diminished, but seldom are crops grown under such high-salinity conditions as those predicted to occur in the proposed retired lands. But they might under the interim salinity conditions predicted to occur with halophytes and with dryland range crops under the proposed conditions of land retirement. In particular, selenium poisoning (commonly termed “alkali disease and blind staggers”) in livestock has been observed and identified as a potential problem/concern associated with the consumption of seleniferous grains and grasses in some arid regions of the Western United States (James et al. (1989). Several plant species have been identified that occur only on seleniferous soils and accumulate and tolerate large concentrations of selenium; for example, the genus *Astragalus* and some *Neptunia* species are “selenium accumulators”(Lauchli, 1993). It is well established that sulfate salinity substantially curtails the uptake of selenium and, thus, its likelihood of causing food and forage toxicities (Tanji et al., 1988). However, studies have not been undertaken to evaluate the degree to which range dryland crops could accumulate selenium under the extreme conditions of salinity and selenium that could accumulate in retired lands; selenium toxicity to consuming humans and to grazing animals have been observed to occur (Rosenfeld and Beth, 1964; Wan, et al., 1988). The latter authors concluded that selenium uptake by the plants they tested was proportional to the concentration in the soil and that alfalfa, barley, beets and tomato were all capable of accumulating selenium to concentrations potentially harmful to animals consuming these products. The range between deficiency and toxicity is narrow; the toxicity threshold for livestock is 4-5 mg Se per kilogram (NRC, 1983).

Reclamation (Leaching) Requirements of Salt-affected Soils

Assuming retired lands are to serve as a land preserve and, possibly, to be used for irrigation again at some later time, it is relevant to know whether their

reclamation requirements would be practical in terms of water, amendments, time and cost. Some evaluations are made in this regard in this section

Saline Soils

The only practical means to remove excess salts in soils is to maintain, over sufficient time, a net downward flux of water in the soil by appropriate water management and, if necessary, by a properly designed drainage system. Salt leaching involves the application of lower-salinity water, the dissolution of soluble salts present in the soil into the applied water, and the transport of the dissolved salt out of the rootzone. In addition to providing the necessary capacity for removing leachate, drainage must also provide a sufficiently deep water table to permit the field to be trafficked and to provide adequate rootzone aeration (Rhoades, 1974; Keren and Miyamoto, 1989). The amount of leaching required to reclaim saline soils is a function of the initial level of soil salinity, the final level desired, the depth of soil to be reclaimed, certain soil and field properties and the method of water application (Rhoades, 1982; Keren and Miyamoto, 1989 and Hanson et al. (1993). While, theories and models have been developed to predict needed leaching, uncertainties in various soil properties and field “factors” limit their usefulness without onsite-calibration. For this reason, more approximating relations have been used as reclamation guidelines. These relations have been based on field experiments, or experience, or field trials. These latter findings have been generalized in the following relation,

$$(C/Co) (dl /ds) = k, \quad [1]$$

where C/Co is the fraction of the initial salt concentration remaining in the profile after application of the amount of water per unit depth of soil, dl /ds . The value of k varies with type of soil and manner of water application. Representative values of k for continuous ponding are 0.3 and 0.1 for clay loam and sandy loam soils, respectively. With water application by intermittent ponding or by sprinkling, k is about 0.1 and not highly soil-type dependent.

The leaching requirement of a representative highly salinized soil was estimated using the above relationship and the following assumptions: 1) the salinity of the retired soil is 100 dS/m, 2) the desired salinity for cropping is 4 dS/m, 3) the depth of soil needing reclamation is 1 foot (because of the localization of salinity within the topsoil under conditions of retirement), 4) the soil is a clay loam, 5) the water will be applied by ponded-flooding and 6) drainage will be available to remove the leachate . For this case, k is 0.3 and the leaching requirement for removal of excess soluble salts is estimated from equation [1] to be 7.5 feet $\{dl = (1)(0.3) / (4/100)\}$.

Boron-affected Soils

The highly salt-affected “retired” soils are expected to be high in boron because the soils and groundwaters of the proposed lands are typically high in boron. Additional leaching is required to lower boron concentrations to levels that are suitable for cropping, because it is more difficult to leach from soils than are the chloride and sulfate salts (because boron is adsorbed by the soil matrix). Based on limited field leaching studies, it has been determined that boron removal may be approximated using equation [1] and a “k” value of 0.6 (which has been concluded to not be highly dependent upon the method of water application (Keren and Miyamoto, 1989). Thus, for soils high in boron, the amount of water required to remove a given fraction of boron is about twice that required to remove soluble salts. Thus for our hypothetical case, about 15 feet of water would have to leach through the salinized soil resulting from land retirement in order to reduce its salinity to a level that would permit cropping. The amount might be less because the adsorption of boron by the soil matrix would delay the rate of boron accumulation in the topsoil compared to salinity. More exact modeling calculations would have to be made to quantify this process and its effect on reclamation requirements versus time since retirement.

Saline/Sodic Soils

The highly salt-affected “retired” soils are also expected to be high in adsorbed sodium, because the soils and underlying groundwaters are saline/sodic and sodium will progressively dominate the cation composition as the less soluble cations (such as calcium and magnesium) are precipitated from the concentrating salts in the topsoil. Sodic soils are typically thought of as being more difficult and expensive to reclaim than saline soils if their permeability and surface tilth has become degraded and if an amendment is needed to replace exchangeable sodium. The reclamation of such soils are frequently undertaken with the use of amendments (such as gypsum and sulfuric acid) to supply calcium salts (to replace excessive exchangeable sodium) and to increase the electrolyte concentration of the infiltrating/leaching water sufficiently to enhance soil permeability. However, the salt-affected soils expected to occur with land retirement will be highly saline/sodic and will contain a large quantity of gypsum precipitated out on the surface and within the topsoil. Such soils should have a relatively high permeability and should leach and reclaim without need of amendments, or extra time (Rhoades, 1982). For this reason, no additional requirements is deemed necessary to remove the predicted accumulation of exchangeable sodium upon land retirement, compared to salinity and, certainly, to boron.

Selenium-affected Soils

Reclamation of selenium-affected lands may be more difficult to predict. Selenium occurs primarily in the form of selenate in oxidized soil conditions (such as retired soils), which has a chemistry similar to sulfate, is readily transported through soils and is highly correlated with salinity (Fujii and Deverel, 1989;

Albasel et al., 1989). The laboratory studies of selenate transport in soil columns of Alemi et al. (1988) concluded that selenate leached through the soils slightly faster than did sulfate. But transformations of selenium in soils make it more difficult to predict its fate.

Studies of the reclamation requirements of salt-affected soils of the “Westside” area were undertaken in the 1960’s before irrigation was undertaken there, though selenate was not included. These results should be very applicable to the estimation of the reclamation of “retired” lands, though the latter may be more salt-affected than these earlier soils. These results should be sought and used to refine the reclamation estimates given above.

Drainage Requirements for Reclamation

The amount of leaching water that must be drained away to achieve reclamation of retired lands is about 15 feet, as estimated above. According to the “Rainbow Report”, the annual drainage amount under existing conditions of irrigation is about 0.6-0.75 feet per year; thus, the 15 feet of drainage required for reclamation is equivalent to about 20-25 years worth of present-day drainage. Such large volumes of drainage occurring over a span of less than one year (reclamation is usually sought over the shortest time possible) would most likely create shallower water table situations than presently exist. Drainage systems would most likely have to be installed to provide the drainage capacity needed to collect and discharge such a large volume of very saline, seleniferous leachate water. Finding a suitable means of disposal for this will likely be just, if not more, difficult than it is for the fractional amounts involved with the drainage now created by irrigation. The load of salt in the reclamation drainage water will be large; the potential for environmental pollution will be correspondingly great. For more on the drainage requirements for the reclamation of salt-affected soils see Rhoades (1974); Keren and Miyamoto, 1989; Hanson et al., 1993).

Alternative Land Retirement Strategies: Soil Degradation Implications

Retirement of “Upslope” Lands

Essentially all of the potential negative consequences of land retirement alluded to above could be avoided by retiring upslope problem lands. These lands produce more drainage per unit area than do the lower-lying less permeable soils recommended for retirement (Hoffman and Schrale, 1988 and Section D.1); thus, less of the former land would need to be retired to achieve the same amount of drainage reduction. Furthermore, this would likely reduce the amount of salts needing discharge on the regional basis because the “throughput” of drainage in the deeper sediments, from which much of the salts present in the “lower-slope” groundwaters are obtained, will be reduced (Rhoades, 1989).

The salinization of the low-salinity soils upon retirement will be greatly reduced, because there will be less salt within the soil profile that can be redistributed into the topsoil, the depth to the groundwater will be higher and the groundwater will have a lower salinity and selenium content. Because such retired land will not become excessively saline, there will be less potential for salt-dust problems. Such land will also have a greater potential for dryland farming, rangeland and wildlife habitat use. The biomass of crops and plants should not contain toxic levels of selenium. The reduction of drainage from the upslope lands would also relieve the hydraulic-pressure on the downslope lands, thereby lowering the groundwater table and potentials for soil salinization.

Use of Limited Irrigation on Retired Land to Offset the Upward Flux

The flux of salt to soil surface in retired lands, having saline soils and groundwaters within 2-3 meters, could be prevented by applying water to the soil surface in an amount sufficient to maintain a net zero flux (i.e., down-up = zero). The water used could even be the groundwater; though the level of soil salinity would be higher than with the use of fresh water, it would still be lower than would occur with a net upward flux. The amount of water needed might be less than that now created by irrigation-induced drainage. However, calculations have not been made to quantify the exact amount of water needed. The management level required for such a strategy could be demanding, since the capacity for an “upward flux” would increase markedly with any increase in water content (because the hydraulic conductivity of the soil would increase). This strategy will only make sense if the water use and drainage amounts are substantially less than those under irrigation.

Another version of this alternative approach would be to include limited winter-cropping and to apply the water in the winter and very-early spring in order to promote limited grass or grain production, or natural vegetation growth, and the required, but very limited, deep percolation. The amount of water to be added would vary with winter rainfall and as needed to achieve the desired plant growth (enough for groundcover, wind-erosion protection, habitat needs, etc) and enough deep percolation to achieve a net “neutral-flux”. No crops requiring substantial irrigation would be grown. This alternative would reduce the problems of surface soil salinization and wind erosion, while providing greater opportunity for rangeland use, “dryland” cropping and habitat creation than would the presently advocated “full retirement” strategy.

Drainage Without Irrigation

Another strategy to minimize soil salinization upon land retirement would be to intentionally increase drainage of these lands to lower the water table depth. The time that it takes for the groundwater to reach the soil surface could be extended appreciably in this manner, while the total discharge of drainage water would be less than that needed under conditions of irrigation (less

0.6-0.75 feet). This strategy would not reduce the drainage disposal as much as would the complete cessation of drainage, but it could reduce the overall degradation of the environment, considering soil salinization, air pollution, and wildlife habitat, in addition to water quality. It also would not eliminate the salinization of the topsoil resulting from the redistribution of the salinity present within the soil profile into it upon the cessation of irrigation.

Rotational-Fallowing of Irrigated Fields

Retirement as now envisioned is essentially permanent, though the 1990 Plan land retirement recommendation does not preclude the possibility of renewing irrigation at some time in the future. Another alternative, which offers advantages over the presently proposed retirement plan, would be to fallow enough fields each year to achieve the same degree of drainage reduction. The fields would be fallowed only periodically in the crop rotation and would be distributed, also on a rotational basis, throughout all of the lands of interest (ideally all of the land producing drainage). This would reduce the drainage disposal need while avoiding the long-term consequences of permanent retirement - soil salinization, wind erosion, etc., while sustaining irrigation and cropping on the land. The fallowing on upslope lands would result in less problems.

D. ECONOMIC ANALYSIS OF LAND RETIREMENT

Introduction

As noted in previous sections of this report, two key features of the land retirement program are that acreage goals are based on an assessment of the extent of lands with poor quality ($\text{Se} \geq 50$ ppm) shallow ground water (water table ≤ 5 ft. from surface) and that parcels to be retired will be selected on a willing seller basis in the case of the CVPIA Land Retirement Program. Other objectives, such as habitat potential, are considered secondarily. At first glance, these may seem to be appropriate criterion for designing a voluntary program that will best address program goals. Whether this is the case depends to a great extent on the exact specification of program goals. This section attempts to make those goals explicit in designing a conceptual framework for examining the program features that are likely to contribute to, or inhibit, attaining an economically efficient land retirement program. The ultimate challenge is to determine the extent, location, and configuration of parcels that would optimally be retired. Unfortunately, an empirical model for making that determination does not currently exist. This section, then, develops a conceptual framework describing key components for such a model. Rather than quantifying program goals, this framework provides a platform for describing inherent tradeoffs and important considerations for decision makers. Towards this end, we first elaborate on the several existing land retirement programs introduced in Section C with an eye towards potential lessons that could be applied to the question at hand. We then turn to the conceptual framework for addressing the drainage problem and a discussion of key components and possible modifications.

Lessons from Existing Land Retirement Programs

Land retirement programs are gaining increasing attention for their potential to address environmental goals. The largest land retirement program in the country is the Conservation Reserve Program (CRP). Originally authorized in the Food Security Act of 1985, the CRP is administered by the

U.S. Department of Agriculture (USDA) with a goal of reducing soil erosion from highly erodible crop lands. The CRP is a medium-term program in which farmers submit bids representing their willingness to accept payment to remove their land from agricultural production. In theory, the program is set up as an auction, with farmers “bidding” for their land, or some portion thereof, to be retired at a given asking price. Ideally, the auction approach would give farmers an incentive to reveal the true opportunity cost of retiring land, and would allow the government to spend only that amount on each parcel retired. In practice, however, regional bid caps were implemented, whereby all land classified as highly erodible and offered at or below the cap would be entered into the program (Smith, 1995). Because the cap was generally known, all offers were at exactly that price, allowing farmers to capture excess rents when the cap exceeded actual opportunity costs. By 1989 the USDA had enrolled 33.9 million acres of cropland into the CRP. In contrast to the land retirement program envisioned for the drainage problem area, which covers a longer time horizon, winning CRP bids retire land for a 10 year period and landowners retain title to the parcel and are free to resume crop production upon contract expiration.

In retrospective analysis, the CRP focus appears to have been on the quantity of land enrolled, rather than on the environmental benefits of enrolling land (Wu and Babcock, 1996). Beginning in 1987, water quality objectives took increasing prominence in CRP design, with filter strips, cropped wetlands, and lands subject to scour erosion gaining eligibility (Osborn, 1995). Nevertheless, a frequent criticism of the program is that selecting parcels on the basis of asking price does not assure that those parcels contributing most to the soil erosion problem are protected.

Targeting those parcels contributing most to water quality problems will increase the environmental effectiveness of the program. Moreover, such targeting is essential to minimize the cost of attaining the environmental objectives. In particular, those parcels that are both highly erodible and adjacent to an impacted water way would receive higher priority for entry into the program than, for example a similar parcel that either is less erodible (e.g., is not steeply sloped) or is farther from the water course. Ribaud et al. (1994) consider the potential for a CRP-like cropland retirement to address agriculture-induced water quality problems nationwide. Water quality improvements considered include reductions in sediment-related problems generally, as well as those associated with reduced fertilizer use on retired lands. Their results suggest that only with a carefully-targeted program will the benefits exceed the costs associated with retiring land. Although originally established to address soil erosion problems, this program has been gaining attention recently for its potential to provide environmental services, such as wildlife habitat (e.g., Szentandrási, et al., 1995). More recent rounds of the CRP have attempted to incorporate environmental objectives by enrolling only environmentally sensitive lands (Wu and Babcock, 1996). About 2.5 million additional acres were enrolled under these new rules.

Prominent among other land retirement programs is the Wetlands Reserve Program (WRP), administered by the USDA in a similar fashion to the CRP, but with an objective of preserving the nation's wetlands. Farmers participating in the WRP sell long-term production easements to the government. In contrast to USDA's programs, the U.S. Department of the Interior's programs are newer and smaller. Interior's Bureau of Reclamation may implement a program to retire agricultural lands in the Colorado River Basin to help reduce salt loading, and enhance fish habitat, in that river (Ekstrand and Johnson, 1995). And, of course, the Bureau has recently embarked on a land retirement program to address the drainage problem (see Section E).

Despite the increasing popularity of land retirement programs for addressing environmental objectives, relatively little comprehensive analysis has been completed evaluating the cost-effectiveness of these programs. For example, in a prominent study of the potential benefits of land retirement for addressing the drainage problem, Stroh (1991) compares the costs of meeting drainage goals through land retirement to costs for four drainage management schemes: treatment, evaporation, dilution, and ground-water pumping. In doing so, he assumes fixed proportions production technology and parameter-based scenarios (e.g., two land values (\$1500 and \$2500/acre), two water use levels (2.5 and 3.0 af/ac), two drainage yield coefficients (0.2 and 0.6 af/ac), etc.). Findings suggest that land retirement can be a cost-effective solution to meeting a drainage objective, but only under a limited set of parameter combinations. Of particular importance is the value placed on applying conserved water in alternative uses. Importantly, source reduction was not an option modeled by Stroh (1991).

Ekstrand and Johnson take a similar approach to evaluating the Colorado River program. They use average CRP payments for the region as a basis for estimating land retirement costs and compare those values with the average per acre costs of structural improvements, such as lining canals and laterals to reduce seepage. Findings suggest that, on average, land retirement would be a lower cost solution to reducing Colorado River salinity levels than structural improvements.

Because crop production and water management activities are exogenous (not included) in both of these studies, comparisons of costs and benefits of alternative measures for addressing the drainage and salt loading problems can be made only on an average cost basis. In contrast, economic optimality would require a tradeoff on the margin. Asking, for example, if one were to spend one additional dollar for drainage reduction, to which program would that dollar be allocated to maximize the benefits in terms of drainage reduction from that expenditure? Further, that comparison must simultaneously consider all options for reducing drainage. Although both studies find land retirement may dominate some options for addressing the environmental problem at hand, neither study is capable of determining the optimal extent of a land retirement program.

This discussion suggests two linked but distinct questions to be addressed in designing a land retirement program with an eye towards environmental benefits. First, what role does land retirement play in addressing the broader environmental objective? Second, which parcels would optimally be retired, and how should a program be designed to ensure that those parcels are retired in a voluntary program? This brief review of existing programs suggests that neither question has been sufficiently addressed in practice. Those experiences do, perhaps, suggest lessons that could be incorporated into an appropriate design of the land retirement component of the drainage management plan.

Characterizing the Economic Optimum

A comprehensive approach to evaluating land retirement goals requires evaluating a model that simultaneously incorporates the costs and benefits of various methods for addressing the drainage problem, including source reduction, reuse, and groundwater management, as well as land retirement. Ideally, such an objective would also account for the environmental benefits of reducing the discharge of drain water volume or constituents. The economically optimal level of control occurs at the point that the marginal cost – the cost for the last unit – of reducing drainage (e.g. water volumes or selenium loads) exactly equals the marginal benefit to the farm and to the environment.

Difficulties in estimating the environmental benefits suggest a second-best approach: determining the least-cost solution to meeting a specified drainage reduction objective. Although not necessarily optimal – because the drainage reduction objective might not be optimal – minimizing the sum of costs to farmers from implementing source reduction and other behavioral changes and those to the government from a land retirement component, subject to the constraint that total drainage not exceed specified levels, will result in an efficient (least-cost) solution to the drainage objective. This specification of the problem is also consistent with the current legal mandate to achieve San Joaquin River water quality standards for discharge from the Grasslands basin and the lack of a drainage outlet from Westlands and Tulare basins.

The solution to this problem, which explicitly identifies the extent of reliance of each drainage reduction method, will occur at the point that the marginal cost of reducing drainage is the same for each method and location. That is, for example, the cost of reducing drainage through source control must exactly equal the cost for the last unit of drainage saved through land retirement. Further, those costs must be the same across all fields in the region.

An empirical model capable of determining that solution would ideally be fully dynamic with simultaneously linked economic and three-dimensional hydrologic models of the region. Unfortunately, to our knowledge, no such model exists. Many important components, however, have been developed, as described elsewhere in this report. A critical missing piece is a generic decision

framework within which the economic and hydrologic components could be meaningfully linked. The next section describes such a framework, albeit, for a slightly narrower question than those described here.

Site Selection for Retired Parcels

Rather than examining land retirement programs in the broader perspective of alternative approaches to addressing the environmental problem, analytical approaches to these programs tend to focus narrowly on land retirement programs themselves. For example, they often take the budget for land retirement or the number of acres to be retired as given. As described above, unless they arise from a comprehensive modeling effort, those values (total acres or dollars to be spent) may imply more or less land retirement than is socially optimal. Nevertheless, budgetary and jurisdictional concerns may motivate a need for a specific solution to the question of which parcels to retire. This is the question addressed here.

The cost-efficient set of parcels to be retired would be determined by maximizing the reduction in regional drainage discharges subject to a budget constraint, as follows:

$$\text{Max}_{\alpha_i} \sum_{i=1}^N \sum_{t=1}^T \alpha_i \left[D_{it}^0(L_i, DP_{it}, \theta_{it}) - D_{it}(L_i, DP_{it}(1 - \alpha_i), \theta_{it}) \right] (1 + \delta)^t$$

subject to:

$$\sum_{i=1}^N \alpha_i \left[P_i(P, \theta_{i1} \dots \theta_{iT}, L_i) + \sum_{t=1}^T m_{it} \right] \leq \bar{B}$$

where:

- i is an index denoting land parcel, $i = 1, \dots, N$;
- t is an index denoting time period, beginning in the first year of the program and ending at time T , the end of the planning horizon (which is a choice variable);
- α_i is a land retirement indicator variable, $\alpha_i = 1$ if parcel i is retired and $= 0$ if parcel i is not retired;
- D_{it}^0 represents baseline drainage levels from each land parcel i in time period t ;
- D_{it} is the drainage level predicted for parcel i in period t in the presence of a land retirement program;
- L is a parameter or vector describing those land characteristics associated with parcel i that do not change with time (principally size, configuration and location, but possibly also including soil type, etc.);

θ is a vector describing the physical characteristics of the site pertaining directly to drainage production arising from a given level of deep percolation, as well as those influencing cropping patterns and irrigation practices, including (but not limited to) depth to high water table and soil salinity;
 DP is deep percolation from irrigation activities on each parcel in each time period and is a function of θ , as well as crop and input prices and water availability;
 δ represents a social rate of discount;
 P_i is the price paid by the government for the parcel;
 P is a vector representing economic factors;
 m_{it} are management costs for each parcel; and
 \bar{B} is the total budget.

The variables describing drainage production deserve a bit more explanation. Determining the appropriate metric for D , while not straightforward, is critical to properly specifying the problem. For example, in the Grasslands basin, D could be specified as pounds of selenium discharged to the San Joaquin River. That is, D_{it}^0 would represent the pounds of selenium predicted to be discharged annually from each parcel in the basin in the absence of a land retirement program. Similarly, D_{it} is total selenium predicted to be discharged from each parcel in each time period in the presence of the land retirement program. In the Westlands and Tulare, basins, however, an appropriate metric is not immediately apparent. One option is to establish a reduction in the volume of collected drain water as the goal for the program. To the extent that lateral flows to drain systems can be estimated, those contributions would be accounted for in this framework. However, absent lateral flows, no benefit would accrue from retiring lands not containing operating drain systems, unless the installation of drain systems is predicted for some time in the future.

In both cases, D is a function of fixed land characteristics (L), physical characteristics of the site influencing, and being influenced by drainage conditions (θ), and irrigation activities (DP). These variables are scaled such that $D = 0$ if $\theta = 0$ and $\partial D / \partial \theta > 0$. A critical point here is that irrigation and drainage values are jointly determined, so that as soil conditions worsen, for example, farmers may adjust by managing water more carefully, switching to more salt tolerant crops, and perhaps, in extreme conditions abandoning the land all together. Deep percolation is assumed to equal 0 if land is retired, but no other restrictions are imposed.

Note that these factors can change over time with or without land retirement programs, and likely will evolve differently depending on the configuration of parcels retired. Thus, D_{it} may diverge from D_{it}^0 even if parcel i is not retired. Hydrologic models such as those described in Section D.1 could be used to quantify these relationships. However, they would first have to be modified to

allow cropping patterns and water applications (and thus deep percolation) to be endogenously determined.

The objective function is discounted to account for the fact that a given (economic) benefit or cost accruing in the near term has a higher value than the same value accruing in the future. Results from dynamic analysis incorporating a discount factor suggest that where tradeoffs must be made, present benefits are preferred to future ones and future costs are preferred to present ones, and this effect will be greater, the higher the discount factor. Including this factor in the model ensures that a parcel with benefits accruing in the near term would be selected, *ceteris paribus*, over a parcel with benefits occurring in greater proportion in the future. Though desirable to include, we recognize that selecting an appropriate discount factor for environmental benefits that are not quantified in an economic metric may be difficult in practice.

The final set of parameters to be defined are those pertaining to the budget constraint. P_i , which is the price paid by the government for the parcel, reflects the present value of profits from crop production forgone as a consequence of retiring the parcel and the size of the parcel, and will vary with drainage conditions; it is expected to fall as drainage and soil conditions worsen, reflecting reduced profitability of crop production. P is a vector representing economic factors – prices received for output and paid for production inputs and input quantity constraints – accounting for the profitability of crop production. Thus specified, P_i represents the minimum payment the farmer must receive to voluntarily retire the parcel. The sum over all parcels, $\sum_i \alpha_i \cdot P_i (P, \theta_{II} \dots \theta_{IT}, L_i)$, then, represents the total cost for purchasing land for the program (recall that $\alpha_i = 0$ when parcel i is not retired and thus although a price exists for which that parcel would voluntarily retire, it does not factor in this calculation). That value plus the annual management costs for each parcel (m_{it}) may not exceed the total budget for the program (\bar{B}).

While attempts have been made to keep this framework as general as possible, several simplifying assumptions have been made. In particular, this formulation assumes that all land purchases occur in the first time period. A more general formulation, and one that would improve the efficiency of expenditures, would also model the optimal purchase date. Such a formulation would require specifying the purchase decision (α) as a decision to retire parcel i in period t . It would also require discounting the purchase price to reflect reduced present value costs for given expenditures pushed into the future. Further, the federal budgeting process – which appropriates monies on an annual basis – could be captured by specifying a set of time-varying budget constraints.

Another issue not fully addressed is the final disposition of water conserved from retired land. As identified in the RR and CVPIA (discussed in

Section C), conserved water is expected to be used to meet environmental needs or for consumptive uses out of the basin. However, if that water is reallocated to other farms within the region, water applications on non-retired plots could increase, as could regional drainage. This outcome would be captured in the above framework as an increase in deep percolation, and thus in D_{it} for non-retired parcels. On the other hand, under conditions of aggregate water scarcity, the value of that water, which should be accounted for as a positive benefit from land retirement (as well as from other conservation activities), is not included in the model. As Stroh (1991) points out, the value placed on alternative uses for conserved water can be critical in determining whether or not land retirement is a part of a cost-effective program for addressing the drainage problem. Perhaps the easiest way to incorporate this value in the above framework is to assume that the government could sell the conserved water and add revenues from water sales to the right hand side of the budget constraint.

Alternative Objectives

Although addressing the drainage problem is the principal objective of the land retirement program, many other objectives could be specified, primary among these are:

1. Maximize habitat benefits from land retired, and
2. Minimize the regional economic impact of addressing the drainage problem.

These and other objectives could substitute for, or be included in, the above framework.

The habitat objective could be incorporated by adding to the constraint set or modifying the objective function. The best land-retirement program could be specified as the one that maximizes the reduction in drainage subject to a budget constraint and to a constraint specifying that the habitat benefits from each retired parcel be positive. For example, following the example used in Section D.1, this could be accomplished by adding to the above framework the constraint that the depth to groundwater (one of the variables included in θ) must be greater than 2.13 meters in each time period for each parcel retired.

Incorporating the habitat objective motivates a need to incorporate the configuration of land to be retired. As noted in Section D.2, parcels in contiguous 5,000 acres blocks provide significantly greater benefits for wildlife than do smaller blocks. Shorter distances to other protected areas or wildlife corridors may also enhance habitat benefits of a given parcel. Thus, the location and configuration of the parcels would have to be considered in addition to other factors already identified. Though computationally intensive, incorporating those

factors into the framework is possible through the use of existing Geographic Information System (GIS) tools and data sets.

Incorporating regional economic impacts poses its own challenges. One option could be to include regional multipliers to estimate the net economic impact of reduced agricultural production on local communities. For example, retiring land could imply fewer inputs purchased from local suppliers and reduced labor needs. On the other hand, to the extent that farmers receiving payments for retiring land reinvest that money on remaining fields or in expenditures elsewhere in the local economy, those funds would offset the direct effect of retiring land. Moreover, this goal could well work in opposition to the drainage reduction goal specified above. Retiring land that would soon be abandoned could have a negligible (or even positive) effect on local economies; losses from reduced agriculture would be minimal because they would have been reduced in any case, and the payment could help keep the landowner solvent. Consequently, retiring that parcel would score well with an objective of minimizing the regional economic impact of the program, despite the possibility that retiring it would have a negligible effect on drainage production.

Finally, multiple-objective planning may be used to explicitly incorporate multiple goals into a single objective function. However, analytical methods for addressing these problems are less well developed than for those specified.

Importance of the Time Horizon

This framework highlights the critical importance of the project time horizon (selecting T). The land retirement program specified in the RR targets land with the worst drainage conditions (e.g., largest θ). In the very short run (1 - 3 years), this strategy may represent a solution to the optimization problem specified above, due to the greatest distance between D_{it} and D_{it}^0 and to the lowest value for P_i . The potential optimality of this result is consistent with the results in Section D.1. This solution may also be optimal in the case that a drainage outlet is maintained, as is the case in the Grasslands basin, and as is modeled in Section D.1.

However, for cases in which a drainage outlet does not exist, such as in the Westlands and Tulare Basins, retiring those parcels of land meeting the RRP conditions may not be optimal if the baseline drainage values, e.g., those predicted for that parcel if the land is not retired, are estimated to fall over time. In fact, the benefit of retiring these parcels will become zero if soil damage reaches the point (say, in year τ) at which agricultural production is no longer sustainable, e.g., $D_{it}^0 = 0$, $t = \tau$ to T . That is, the parcel will be taken out of production within the time horizon with or without participation in a land-retirement program. Consequently, D_{it} will not diverge from D_{it}^0 and retiring that parcel will not add to the value of the objective function. In this case, the

program may well achieve other objectives, such as income distribution, but will not be an efficient program for addressing drainage reduction benefits. Conversely as is the Case in Section D.1, the difference between D_{it} and D_{it}^0 increases with time and the benefit of land retirement increases.

The results in Section D.1 also highlight the importance of the time horizon when habitat benefits are considered. For the case examined, habitat benefits of retiring a down-gradient parcel accrue only in the short to medium term (3-13 years in the scenario modeled), and not in the immediate or long term.

V. SUMMARY AND RECOMMENDATIONS

In the 1990 Management Plan, land recommended for retirement included areas with shallow groundwater and high selenium concentration. Land retirement would reduce groundwater influx to shallow groundwater impacted lands, along with a reduction in drainage volume requiring discharge to the San Joaquin River or to evaporation ponds. Retirement would be until completion of the development of an efficient, viable, and economical treatment method for the removal of selenium and/or development of other solutions. Required management for retired lands with high selenium concentration in shallow groundwater would include careful monitoring and management to maintain lowered water tables and prevent soil salinization and selenification.

In this follow-on report hydrologic, biologic, and soil consequences of land retirement are the foundation for recommending an economics-based land retirement selection approach. First the hydrologic, biologic and soil consequences of land retirement are summarized and recommendations are presented. Finally the summary of economic consequences provides the setting for the land retirement selection approach.

Hydrologic Models

The most important criterion used in the report for determining the effects of land retirement and appropriate post-retirement management is the depth to shallow groundwater at which upward salt transport could lead to soil salinization.

In the hydrologic models of Purkey and Wallender (1998) and Belitz and Philips (1992) this depth is set at 7 feet (Hydrology section IV-A). In Soils section IV-C of this report, Rhoades states that this depth could be up to 10 feet depending on specific conditions, but is typically about 5 feet during the summer months for the soil type characteristic of the areas proposed for land retirement. Not only is the groundwater depth at which salinization of the soil surface can occur variable depending on soil and other conditions, but the depth of groundwater with respect to geographic area is also variable from year to year and season to season.

This report uses various terminology to describe landscape position such as up-gradient, down-gradient, up slope, down slope, upland, lowland, etc. Within most report contexts, these terms are used in a relative sense rather than in reference to specific landforms or regions, even in the context of specific studies. As defined in section IV-B, upland habitat refers only to dry-land habitats, not wetlands, and can occur on either upslope or downslope lands (hydrologically). The term lowlands, as used in the first sentence of Section IV-B, Biotic Communities Historically Occurring within the Program Study Area, refers to lands that supported seasonally fluctuating wetlands at some time in the past.

The hydrologic model of Purkey and Wallender (1999) presented in Section IV-A is set in the Grasslands subarea. Five strategies of land retirement are evaluated and compared to a baseline condition. The strategies are down-gradient lands with drains either open or closed, up-gradient lands, and contiguous lands with drains either open or closed. Model results and conclusions are dependent on the model grid size and the specific assumptions used to determine aquifer conditions. In terms of the objectives of drainage reduction and lowering of the water table, the model indicates that:

1. retirement of large contiguous land parcels both up- and down-gradient would provide the greatest overall reduction in drainage volume and be most effective in lowering the water table;
2. retirement of down-gradient parcels with an existing high water table would reduce drainage volume to a greater extent than retirement of the same amount of land up-gradient of the drainage problem area in the short-term;

3. retirement of undrained, up-gradient parcels would provide significant drainage reduction in un-retired, immediately down-gradient areas (i.e., a patchwork strategy) in the short-term, and provide the greatest long-term relief.

In terms of agricultural suitability remaining after retirement (i.e., irrigated, undrained land with a water-table below 7 feet), the model indicates that:

1. retirement of up-gradient parcels removes from production lands unaffected by drainage problems, but prevents future up-gradient migration of the shallow water table;
2. retirement of down-gradient parcels removes drainage impaired lands from production, but does not stem the long-term up-gradient expansion of the zone of shallow groundwater.

The result under the down-gradient retirement strategy is similar to that under baseline conditions, where eventual soil water-logging and salt accumulation could limit options available to future wildlife habitat management. In terms of habitat management, the model indicates that:

1. habitat on retired up-gradient parcels would be unaffected by soil water-logging and salt;
2. habitat on retired down-gradient parcels would be degraded by soil water-logging and salinization.

The model shows that not all needs can be served by one land retirement strategy. For example, if the goal is to create a sustainable, integrated production/habitat system, then up-gradient retirement could emerge as the most logical strategy, even if it yields less near-term drainage reduction. However, this scenario is unlikely under a willing seller retirement program.

Report Recommendations

Balancing land retirement objectives requires: 1) a clear articulation of land retirement priorities associated with each objective, 2) a determination of an appropriate time frame for impact analysis, 3) an analysis of the impacts of transfer or reallocation of retired land water rights, and 4) a consideration of the fate of selenium on retired lands. Results of other hydrologic models developed for the western San Joaquin Valley (e.g., Belitz and Phillips, 1992; Wu, 1998) and further refinements of all models also need full consideration to enable evaluation of the benefits of various retirement and management alternatives. For example, the effect of increased source reduction on uplands under continued cultivation is included in the Belitz and Philips model, but not in the Purkey and Wallender model.

Biologic Resources

Many benefits to wildlife are possible through the land retirement program. An increase in the amount of wildlife habitat, and the connectivity between natural land parcels, should substantially enhance wildlife resources in the San Joaquin Valley. Reductions in the volume of agricultural drainwater and selenium concentration in the drainwater which should occur as a result of land retirement should also benefit Valley wildlife, particularly aquatic species. The restoration of native plant and animal communities on retired land may increase biodiversity, and will provide important habitat for both endangered and non-endangered Valley wildlife.

Negative effects from land retirement are also possible, including selenium impacts and the potential for establishment of undesirable weedy plant communities, but given the lack of available information regarding the land retirement process, any conclusions at this point regarding negative impacts are premature. Comparisons of contaminant concentrations in soils, vegetation, biota, surface waters, and ground waters associated with land parcels available for retirement, and of those retired, will be made with Kesterson Reservoir.

One of the ecological goals of land retirement is meaningful restoration of wildlife habitat on retired agricultural lands. Creation of a contamination hazard on retired lands is in conflict with this goal and is not an expected outcome. Trigger mechanisms should be in place for contamination contingencies which, when observed, will set into motion appropriate managerial action. Any indication that contamination is occurring on retired lands will lead to immediate steps to remediate the effects.

Recommendations

Each retired parcel will be different, and hence different outcomes may occur on each piece of land. In order to best establish and maintain any particular parcel, a site-specific habitat management plan should be developed which explicitly states the goals and objectives for that parcel. Each management plan should be based on the adaptive management concept (Holling 1978) to take advantage of changing situations in the field, and should include protocols which address specific revegetation and monitoring needs. The continued type and degree of management of a parcel should be dependent on the results of the monitoring. Monitoring tasks for each parcel should include measurement of selenium levels in soil, ground and surface water, vegetation, and animals. Groundwater levels should also be closely monitored to determine the effects of retirement on retired and nearby lands.

It would be a prudent step to test management strategies on a small scale prior to implementation of expensive and labor-intensive practices on large areas

of land. Appropriate test plots might range from a few hundred to a few thousand acres. With this approach, methods to promote habitat restoration can be explored and manipulated in a scientifically valid manner with control and experimental plots. Results can then be used to prepare adaptive management plans for specific parcels.

Monitoring of the disposition of freed-up water available from land retirement is needed as well as an analysis its potential usefulness in meeting the needs of habitat restoration and wildlife protection. It is hoped that some restored habitat would ultimately be suitable for endangered, threatened, or other sensitive species, and would be managed as reserves for those species. In fact, the recovery plan for upland species of the San Joaquin Valley (USFWS 1998) identifies land retirement as instrumental in the recovery of many endangered, threatened, and sensitive species.

Soil Resources

A preliminary evaluation of the potential for soil salinization of land retired from irrigation was presented in Section IV-C. The evaluation is based on three analyses by staff of the USDA Salinity Laboratory, including two preliminary modeling studies of water and salt transport in unsaturated soils in arid climates, as well as field observations and other professional experience. The evaluation includes:

- X the fate of the salts present in the soil profile at the time of land retirement;
- X the upward transport of salts from groundwater through the vadose zone to the soil surface following land retirement where groundwater is within approximately 10 feet of the soil surface;
- X the suitability of retired lands for other uses, i.e., alternate land uses including dry-land farming and wildlife habitat; and
- X the management of the potential hazard of wind dispersed salt and toxic concentrations of trace elements such as selenium.

The modeling studies generally assumed initial conditions of a water table depth of 6 feet, soil hydraulic characteristics of loamy soils, no rainfall, and no salt precipitation. If the poorly drained lands now proposed for retirement were to be permanently removed from irrigation and left un-managed, under the specified conditions a high likelihood exists for the development of excessive soil salinization. The soils could be expected to achieve salinity levels exceeding 100 dS/m within 5-10 years of the time of retirement, given a sustained water table within 2-3 meters of the soil surface. Trace elements such as selenium could be a component of the accumulated salt, and retired land soils could also become seleniferous by accumulating selenium near the soil surface. Un-managed

salinized land would eventually support little or no plant growth. In the absence of vegetative ground-cover, surface salt and selenium crusts could become susceptible to wind erosion and dispersion. Although no study has been conducted, it is possible that wind-blown salt and selenium from retired land sources could create downwind air quality degradation and other environmental problems.

The conclusion of the modeling study is that land retirement to reduce drainage volume and related water quality problems could occur at the expense of degrading equally important soil, air, and land resources without implementation of special management. Retired lands that could become excessively salinized over time would become unsuitable for sustained agriculture and even dryland farming and non-irrigated rangeland. Crops and especially forages grown on lands during the interim period between retirement and excessive salinization, may increasingly contain selenium at elevated concentrations. Given the large amounts of water that would be required to reclaim lands salinized by retirement and the lack of drainage capacity to remove substantial amounts of leachate, land retirement as now proposed would not serve the purposes of land preserves (as suggested in the 1990 Management Plan), because their reclamation would be impractical to achieve. Additionally, the disposal of the salt-load generated by any reclamation activity would have off-site environmental consequences. Given the high level of salinization and possibly selenification likely to occur over time (under model simulated conditions), the wildlife habitat value of un-managed and degraded retired lands could also decline, limiting use as upland wildlife habitat.

The results of the USDA Salinity Laboratory modeling studies as described above predict a worst case scenario. Therefore, further studies and a monitoring program are needed to establish more information on a site-specific basis before a substantial amount of land retirement is undertaken. To avoid the problems identified above, proposed alternative land retirement scenarios are described below.

Alternative Retirement Strategies

A number of alternative strategies to permanent land retirement and complete cessation of irrigation are presented that could still achieve the objectives of the 1990 SJVDP Management Plan land retirement recommendations. These alternative strategies could meet the objectives of increased water conservation and reduced drainage volume, while minimizing or avoiding the degradation of soil and reduced capacity for plant growth that could result from the 1990 recommended plan. The alternative strategies include: 1) retirement of upslope lands that contribute to downslope shallow groundwater, 2) implementation of rotational-, distributed-, or periodic-fallowing programs, 3) use of limited irrigation of winter crops to counter the upward transport of salt from shallow groundwater and avoid salinization and wind-

erosion, while providing plant growth opportunities for both agricultural and upland wildlife habitat uses, and 4) retirement with the installation of drains to lower the water table to much deeper depths than presently planned and with periodic reuse of drainage as irrigation to offset the upward transport of salt to the soil surface. Installation and operation of drainage systems, irrigation of winter crops in amounts sufficient to partially leach salt from the upper soil horizons, and pumping of shallow groundwater for reuse as irrigation to accomplish both shallow groundwater level reduction and limited leaching, are the management measures that may be necessary to prevent excessive salinization of retired lands as mentioned above.

Recommendations

Additional research, especially data collection and refinement of modeling simulations based on current monitoring, needs to be undertaken to better quantify the transient salt-transport/chemical processes involved in land retirement and management in order to predict the ultimate fate of retired lands and to select alternative strategies that will avoid or at least minimize the potential problems of soil degradation anticipated to occur over time under the present land retirement plan. More site-specific and current soil and groundwater data need to be obtained and rainfall effects need to be considered in order to test and verify the modeling predictions. Monitoring programs, including soil salinity, wind-erosion, and selenium levels in crops, forage, soils, water, and biota, must be developed and incorporated into any implemented plan of land retirement to assess/assure the effectiveness of the program. Management requirements and costs need to be fully developed before retirement is implemented; these requirements should be based on modeling evaluations which incorporate the vadose zone processes, especially the soil-salinity processes, with hydrologic and selenium transport processes operative in the study area. Management objectives should be extended beyond water-quality protection to include other important natural resources meriting protection-soil, air and wildlife-and agricultural sustainability.

Economic Evaluation

Whether, and to what extent, land retirement is an efficient tool for addressing the drainage problem is an empirical question to which the answer on a regional basis does not yet exist. The conceptual framework presented in Section IV-D for determining a cost-effective approach to implementing a land retirement program provides a structure for discussing 1) key factors to be determined in designing an efficient land retirement program, 2) the appropriate role for existing tools, and 3) areas of uncertainty or missing information. An assessment of the overall extent of the land retirement program optimally requires the simultaneous determination of the precise parcels to be retired. Designing a socially optimal land retirement program would require estimates of the environmental benefits of addressing the drainage problem. Absent the

benefits estimates, a second-best approach would be to solve for the extent, configuration, and location of parcels to be retired in a broad assessment that balances the costs and effectiveness of land retirement with those of alternative methods for achieving a given drainage reduction objective, such as source control, reuse, and groundwater management. A third, more narrow approach is to select the combination of parcels to be retired to achieve the greatest benefit for a given programmatic expenditure. A narrow focus that examines the site selection process while taking as fixed the quantity of land to be retired or the total expenditures on land retirement provides only a partial answer to the more general question that places land retirement in the context of the broader set of possible solutions to the drainage problem.

The economic evaluation concludes that retiring parcels based on such simple assessments as depth-to-the-water-table and selenium concentration greater than 50 ppb will not necessarily yield a cost-effective land retirement program. To the extent that drainage problems are caused by irrigation activities on overlying fields and the effects of those irrigation activities are evaluated as depth-to-the-water-table, the consequences of those activities are born by the farmer. Because no measures of social efficiency of land retirement have been developed, a more efficient approach would be to target for retirement those parcels creating the largest external costs as determined either by discharge of drainage to the environment or through lateral flows onto neighboring parcels.

Land Retirement Selection Approach

Implementation of a successful land retirement program may require a system that would weigh independently the benefits of drainage reduction, selenium reduction, habitat creation, water transfer, and removal of lands from the agricultural community that are no longer productive. Such an approach would also serve to identify target lands within each use category and each subarea.

To evaluate a property for retirement, several components need to be defined not the least of which are the measures that are used to judge success. Specifying factors for measuring program benefits and costs can be challenging, for reasons of regional variability and conflicting objectives. For example, the primary land retirement objective could be to reduce selenium loads discharged to the San Joaquin River (Grasslands subarea) or evaporation ponds (Tulare/Kern subarea) or to reduce deep percolation to shallow groundwater tables requiring management (Westlands subarea). An efficient program would retire parcels contributing the greatest benefit to a given objective per program dollar expended. Alternative objectives could best be incorporated as secondary concerns. Given maximization of reductions in selenium loads as a primary objective, associated alternative objectives could be assuring a minimum acceptable level of wildlife habitat quality for each parcel retired and a minimal acceptable level for local economic impacts.

In order for measurements of program benefits to have significance, the appropriate "without-program" conditions must be defined and determined. For example, lands abandoned outside the land retirement program would not provide a benefit attributable to the retirement program.

The time period for program duration could significantly influence the selection of preferred parcels for retirement. Some parcels may provide only short-term benefits, while others could have greater long-term benefits. For example, the latter parcels would not be selected in a program with short-term objectives, but could be optimal in a comprehensive program with long-term objectives.

A monitoring program developed on a well-defined scientific basis and utilizing specific measurements that receive periodic review is needed to help target, weigh independently, and achieve the competing goals of sustainable agriculture, drainage reduction, selenium reduction, environmental protection, habitat restoration, and acquisition of water.

The sequential approach to select and manage retired land is:

- identify primary objectives and alternative objectives specific to a given region or subarea;
- formulate area-specific land retirement scenarios and evaluate hydrologic, biologic, soils and economic consequences in the short term and the long term;
- manage retired lands to reduce the risks of salinization and selenification, based on dynamic hydrologic, biologic and soil conditions.

REFERENCES

- Abrams, M. M., R. B. Burau and R. J. Zasoski. 1990. Organic selenium distribution in selected California soils. *Soil Science Society of America Journal* 54:979-982.
- Albasel, N., P. F. Pratt and D. W. Westcot. 1989. Guidelines for selenium in irrigation waters. *J. Environ. Qual.* 18:253-258.
- Alemi, M. H., D. A. Goldhamer and D. R. Nielsen. 1988. Selenate transport in steady-state, water-saturated soil columns. *J. Environ. Qual.* 17:608-613.
- Alemi, M. H., D. A. Goldhamer, M.E. Grismer and D. R. Nielsen. 1988. Elution of selenium from contaminated evaporation pond sediments. *Journal of Environmental Quality* 17:613-618.
- Anderson, D.C. 1987. Evaluation of habitat restoration on the Naval Petroleum Preserve #1, Kern Co., CA. Unpubl. Rept. To US Dept. of Energy and Chevron U.S.A. , E.G. and G. Energy Measurements, Goleta, CA. 41pp+
- Aronson, J. A. 1989. HALOPH: A Data Base of Salt Tolerant Plants of the World, The University of Arizona, Tucson, 75 pp.
- Belitz, K. and S.P. Phillips. 1992. Simulation of Water - Table Response to Management Alternatives, Central Part of the Western San Joaquin Valley, California. Water - Resource Investigations Report 91 - 4193. USGS, Sacramento, CA., 41 pp.
- Belitz, K., Phillips, S.P. and Gronberg, J.M.. 1992. Numerical simulation of ground-water flow in the central part of the western San Joaquin Valley, California. U. S. Geol. Surv. Open-File Rep. 91-535.
- Belitz, K., and Phillips, S.P. 1995. Alternative to agricultural drains in California's San Joaquin Valley: Results of a regional-scale hydrogeologic approach. *Water Resources Research*. 31(8).
- Benson, M. 1997. Success of Feds' Land Plan Rests on Pride and Money. *Wall Street Journal*, California. August 27, 1997. New York, New York.
- CH2M Hill. 1992. Ecological Risk Assessment for Kesterson Reservoir. Prepared for the U.S. Bureau of Reclamation, Mid-Pacific Region, September 1992.

- CH2M Hill. 1995. Kesterson Reservoir 1995 Biological Monitoring Report. Prepared for the U.S. Bureau of Reclamation, Mid-Pacific Region, December 1995.
- CH2M Hill. 1996. Kesterson Reservoir 1996 Biological Monitoring Report. Prepared for the U.S. Bureau of Reclamation, Mid-Pacific Region, December 1996.
- CH2M Hill. 1998. Kesterson Reservoir 1997 Biological Monitoring Report and 1998 Biological Monitoring Plan. Prepared for the U.S. Bureau of Reclamation, Mid-Pacific Region, February 1998.
- Clark, D. R., Jr. 1987. Selenium accumulation in mammals exposed to California irrigation drainwater. *Science of the Total Environment* 66:147-168.
- Deverel, S. J. and R. Fujii. 1988. Processes affecting the distribution of selenium in shallow groundwater of agricultural areas, western San Joaquin Valley, California. *Water Resources Research* 24(4):516-524.
- Dinar, A. and Zilberman, D. (eds.) 1991, *The Economics and Management of Water and Drainage in Agriculture*. Kluwer Academia Publishers, Boston, Massachusetts, 946 pages.
- Ekstrand, Earl and Richard Johnson. 1995. Water and Wildlife Enhancement with Land Retirement. *Water Policy and Management* 20(1):541-544.
- Frankenberger, W.T. and Benson, S., (eds.) 1994, *Selenium in the Environment*, Marcel Dekker, Inc, 456 pages.
- Frankenberger, W.T. and Engberg, R.A., (eds.) 1998, *Environmental Chemistry of Selenium*, Marcel Dekker Inc., New York, 736 pages.
- Fujii, R., S. J. Deverel and D. B. Hatfield. 1988. Distribution of selenium in soils of agricultural fields, western San Joaquin Valley, California. *Soil Science Society of America Journal* 52:1274-1283.
- Fujii and S. J. Deverel 1989. Mobility and distribution of selenium and salinity in groundwater and soil of drained agricultural fields, western San Joaquin Valley of California. In L. W. Jacobs (ed.), *Selenium in Agriculture and the Environment*, Soil Science Society of America Special Publication No. 23, SSSA, Madison Wisconsin. pp. 195-212.

- Fujii., R. and Swain, W.C., 1995, Areal Distribution of Selected Trace Elements, Salinity, and Major Ions in Shallow Ground Water, Tulare Basin, Southern San Joaquin Valley, California, 67 pages and one plate.
- Gardner, W. R. 1960. Soil water relations in arid and semi-arid conditions. In *Plant Water Relationships in Arid and Semi-arid Conditions: Rev. of Res.* (UNESCO) 15: 37-61.
- Gardner, W. R. and M. Fireman. 1957. Laboratory studies of evaporation from soil columns in the presence of a water table. *Soil Sci.* 85:244-249.
- Gilliom, R.J., et al. 1989. (draft), *Preliminary Simulation of Effects of Land Retirement on Drainage Problems*: U.S. Geological Survey, unpublished report.
- Griggs, T. F., J. M. Zaninovich and G. D. Werschull. 1987. Historic native vegetation map of the Tulare Basin, CA. Pp. 111-118 *In* D. F. Williams, S. Byrne and T. A. Rado (eds.) Endangered and sensitive species of the San Joaquin Valley, California.
- Hanson, B., S. R. Grattan and A. Fulton. 1993. Agricultural salinity and drainage: A handbook for water managers. University of California Irrigation Program publication, University of California, Davis, pp.141.
- Heady, H. F. 1977. Valley grassland. *In* Barbour, M.G. and J. Mayor (eds.) Terrestrial Vegetation of California. John Wiley & Sons, New York, NY.
- Hoffman, G. J. and G. Schrale, 1988. Management strategies to reduce drainage from irrigated agriculture, Proc. 1988 International Winter Meeting of the ASAE, Chicago, Illinois, December 13-16, 1988.
- Holland, R. F. 1986. Preliminary Descriptions of the Terrestrial Natural Communities of California. California Department of Fish and Game. 156 pp.
- Holling, C. S., ed. 1978. Adaptive environmental assessment and management. Wiley, New York, 377 pp.
- James, L. F., K. E. Panter, H. F. Mayland, M. R. Miller and D. C. Baker. 1989. Selenium poisoning in livestock: a review and progress. pp. 123-131. *In* L. W. Jacobs (ed.), *Selenium in Agriculture and the Environment*, Soil Science Society of America Special Publication No. 23, SSSA, Madison Wisconsin.

- Kelly, P. A., and J. T. Rotenberry. 1993. Buffer zones for ecological reserves in California: replacing guesswork with science. Symposium on the Interface between ecology and land development in California (J. E. Keeley, ed.). Occidental College, U.S.A. 11 pp.
- Keren, R. and S. Miyamoto. 1989. Reclamation of saline, sodic, and boron-affected soils. In K. K. Tanji (ed.) *Agricultural Salinity Assessment and Management*, ASCE Manuals & Reports Engineering Practice Publication 71, ASCE, New York, pp. 410-431.
- Kruse, E. G., L. Willardson and J Ayars. 1990. On-farm irrigation and drainage practices. In K. K. Tanji (ed.), *Agricultural Salinity Assessment and Management*, ASCE Manuals & Reports Engineering Practice Publication 71, ASCE, New York, pp. 349-371.
- Lauchli, A. 1993. Selenium in plants: uptake, functions, and environmental toxicity. *Bot. Acta* 106:455-468.
- Maas, E. V. 1990. Crop salt tolerance. In K. K. Tanji (ed.) *Agricultural Salinity Assessment and Management Manual*. ASCE, New York, pp. 262-304. 1990.
- Mays, R. 1997. *CVPIA Land Retirement Program*. U.C. Salinity-Drainage Task Force. March 28, 1997. Sacramento, California.
- Miyamoto, S. 1996. Salt tolerance, water use, and irrigation scheduling of halophytes. In R. Choukr-Allah, C. V. Malcolm and A. Hamdy (eds.), *Halophytes and Biosaline Agriculture*, Marcel Dekker, New York, pp. 181-220.
- Moore, S.B., J. Winckel, S.J. Detwiler, S.A. Klasing, P.A. Gaul, N.R. Kanim, B.E. Kesser, A.B. DeBevec, K. Beardsley, and L.K. Puckett. 1990. Fish and Wildlife Resources and Agricultural Drainage in the San Joaquin Valley, California. SJVDP, Sacramento, CA., 6 sections and 2 appendices.
- National Research Council. 1976. Selenium. Comm. On Med. And Biol. Effects of Environ. Pollut., Nat'l Acad. of Sci., Washington, DC.
- National Research Council. 1983. Exact reference not available.
- Neuman, S.P., and Witherspoon, P.A. 1970. Variational principles for confined and unconfined flow of groundwater. *Water Resour. Res.* 6(5).
- Neuman, S.P., and Witherspoon, P.A. 1971. Analysis of Nonsteady flow with a free surface using the finite element method. *Water Resour. Res.* 7(3).
- Nielsen, D.R., Biggar, J.W., and Erh, K.T. 1973. Spatial variability of field-measured soil water properties. *Hilgardia*. 42(7).

- Noss, R. F. and A.Y. Cooperrider. 1994. Saving nature's legacy: protecting and restoring biodiversity. Island Press, Washington, DC, 416pp.
- Ohlendorf, H. R. 1989. Bioaccumulation and effects of selenium in wildlife. In L.W. Jacobs (ed.), Selenium in Agriculture and the Environment, pp.133-177. American Society of Agronomy and Soil Science Society of America, Madison, WI.
- Ohlendorf, H. R., A.W. Kilness, J. L. Simmons, R.K. Stroud, D. J. Hoffman, and J. F. Moore. 1988b. Selenium toxicosis in wild aquatic birds. *Journal of Toxicology and Environmental Health* 24:67-92.
- Ohlendorf, H. R., D. J. Hoffman, M. K. Saiki, and T. W. Aldrich. 1986. Embryonic mortality and abnormalities of aquatic birds: apparent impacts of selenium from irrigation drainwater. *Science of the Total Environment* 52:49-63.
- Ohlendorf, H. R., R. L. Hothem, and T. W. Aldrich. 1988a. Bioaccumulation of selenium by snakes and frogs in the San Joaquin Valley, California. *Copeia*, 1988(3):704-710.
- Ohlendorf, H. R., R. L. Hothem, T. W. Aldrich, and A. J. Krinitsky. 1987. Selenium contamination of the grasslands, a major California waterfowl area. *Science of the Total Environment* 66:169-183.
- Osborn, C. Tim, Felix Llacuna, and Michael Linsenbigler. 1995. The Conservation Reserve Program: Enrollment Statistics for Signup Periods 1-12 and Fiscal Years 1986- 93. United States Department of Agriculture, Economic Research Service, Statistical Bulletin Number 925.
- Paveglio, F. L., and S. D. Clifton. 1988. Selenium accumulation and ecology of the San Joaquin kit fox in the Kesterson national wildlife refuge area. Prepared for the U.S. Bureau of Reclamation, Sacramento, CA.
- Paveglio, F. L., K.M. Kilbride and C. M. Bunck. 1997. Selenium in aquatic birds from central California. *Journal of Wildlife Management* 61(3):832-839.
- Poister, D. and T. K. Tokunaga. 1992. Selenium in Kesterson Reservoir ephemeral pools formed by groundwater rise: II. Laboratory experiments. *Journal of Environmental Quality* 21:252-258.
- Presser, T. S. and H. M. Ohlendorf. 1987. Biogeochemical cycling of selenium in the San Joaquin Valley, California. *Environmental Management* 11:805-821.

- Presser, T. S., M. A. Sylvester and W.H. Low. 1994. Bioaccumulation of selenium from natural geologic sources in western states and its potential consequences. *Environmental Management* 18(3):423-436.
- Preston, W. L. 1981. Vanishing Landscapes: Land and Life in the Tulare Lake Basin. University of California Press, Berkeley, California. 278pp.
- Purkey, D.R., Wallender, W.W., and G.E. Fogg 1998a. A Non-Dupuit Treatment of Transient, Unconfined Groundwater Flow: I. Model Retrieval and Enhancement. (submitted)
- Purkey, D.R., Wallender, W.W., and G.E. Fogg 1998b. A Non-Dupuit Treatment of Transient, Unconfined Groundwater Flow: II. Model Application in the Western San Joaquin Valley, California. (submitted)
- Purkey, D.R. and Wallender, W.W. 1998. The Drainage Reduction Potential of Land Retirement Strategies for the Western San Joaquin Valley of California. (submitted)
- Rhoades, J. D. 1974. Drainage for salinity control. In Jan van Schilfgaarde (ed.), *Drainage for Agriculture*. Agronomy Monograph 17:433-461.
- Rhoades, J. D. 1982. Reclamation and management of salt-affected soils after drainage. *Proc. First Annual western Provincial Conf., Rationalization of Water and Soil Research and Management*, Lethbridge, Alberta, Canada, pp. 123-197.
- Rhoades, J. D. 1989. Effects of salts on soils and plants. *Proc. Specialty Conf. Sponsored by ASCE, Irrigation & Drainage Division and Water Resour. Planning & Management Div., July 17-20, 1989, University of Delaw, Newark, New Jersey, ASCE, New York.*
- Rhoades, J. D. 1989. Intercepting, isolating and reusing drainage waters for irrigation to conserve water and protect water quality. *Agr. Water Mgt.* 16:37-52.
- Rhoades, J. D., S. M. Lesch, R. D. LeMert and W. J. Alves. 1997. Assessing irrigation/drainage/salinity management using spatially referenced salinity measurements. *Agr. Water Mgt.* 35:147-165.

- Ribaudo, Marc O., C. Tim Osborn, Konyar Kazim. 1994. Land Retirement as a Tool for Reducing Agricultural Nonpoint Pollution. *Land Economics* 70(1):77-87.
- Rosenfeld, I. and O. A. Beth. 1964. Selenium: geobotany, biochemistry, toxicity and nutrition. Academic Press, New York.
- San Joaquin Valley Drainage Program, 1990, A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley, Sacramento, California, 183 pages.
- San Joaquin Valley Drainage Program, August, 1989, Preliminary Planning Alternatives for Solving Agricultural Drainage and Drainage-Related Problems in the San Joaquin Valley, SJVDP, Sacramento, California, 5 chapters.
- San Joaquin Valley Drainage Program. 1990. Fish and Wildlife Resources and Agricultural Drainage in the San Joaquin Valley, California. Vols I, II. 707pp+appendices.
- San Joaquin Valley Drainage Program. 1990. A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley. Sacramento, California.
- Skorupa, J. P. 1998. Selenium poisoning of fish and wildlife in nature: Lessons from twelve real-world examples. *In* W.T. Frankenberger, Jr., and R.A. Engberg (eds.), Environmental Chemistry of Selenium, pp.315-354. Marcel Dekker, Inc., New York.
- Skorupa, J. P. and H. M. Ohlendorf. 1991. Contaminants in drainage water and avian risk thresholds. *In* A. Dinar and D. Zilberman (eds.), The Economics and Management of Water and Drainage in Agriculture, pp. 345-368. Kluwer Academic Publishers, Boston.
- Smith, Rodney B. W. 1995. The Conservation Reserve Program as a Least-Cost Land Retirement Mechanism," *American Journal of Agricultural Economics*, 77(1):93-105.
- Stroh, C.M., Land Retirement as a Strategy for Long-Term Management of Agricultural Drainage and Related Problems. 1991. Pages 117-141 *in* A Dinar and D. Zilberman (eds.), *The Economics and Management of Water and Drainage in Agriculture*. Kluwer Academia Publishers, Boston, Massachusetts.

- Stroh, Craig M. 1991. Land Retirement as a Strategy for Long Term Management of Agricultural Drainage and Related Problems in Dinar, Ariel; Zilberman, David, eds. The Economics and Management of Water and Drainage in Agriculture. Norwell, Mass. and Dordrecht: Kluwer Academic. p.117-41.
- Stromberg, M. R. and P. Kephart. 1996. Restoring native grasses in California old fields. Restoration and Management Notes 14(2):102-111.
- Suarez, D.L. and J. Simunek. 1997. UNSATCHEM: Unsaturated water and solute transport model with equilibrium and kinetic chemistry. Soil Sci. Soc. Amer. J. 61:1633-1646.
- Swain, D.G., 1990, Documentation of the Use of Data, Analysis, and Evaluation Processes that Resulted in the SJVDP Recommended Plan. Tech. Inf. Rec. SJVDP, Sacramento, CA. 15 chapters and 6 appendices.
- Szentandrasi, Susanne, Stephen Polasky, Robert Berrens, and Jerome Leonard. 1995. Conserving Biological Diversity and the Conservation Reserve Program" Growth and Change. 26(3):383-404.
- Tanji, K. K. and F. Karajeh. 1992. Saline drainwater reuse in agroforestry systems. J. Irrig. And Drain. Engrg. 119:170-180.
- Tanji, K.K , L. Valoppi, and R. C. Woodring. (eds.) 1988. Selenium contents in animal and human food crops grown in California, University of California, Division of Agricultural Sciences, Special Publication No. 3330, 1988.
- Tanji, K., A. Lauchli and J. Meyer. 1986. Selenium in the San Joaquin Valley. Environment 28(6):20-31.
- Tokunaga, T. K. and S. M. Benson. 1992. Selenium in Kesterson Reservoir ephemeral pools formed by groundwater rise: I. A field study. Journal of Environmental Quality 21:246-251.
- Tokunaga, T. K., I. J. Pickering and G. E. Brown, Jr. 1996. Selenium transformations in ponded sediments. Soil Science Society of America Journal 60:781-790.
- U. S. Salinity Laboratory Staff. 1954. Diagnosis and Improvement of Saline and Alkaai Soils. U. S. Dept Agric. Handbook 60.
- United States Department of the Interior. 1997. Central Valley Project Improvement Act Land Retirement Interim Guidelines. Interagency Land Retirement Team. 12pp.

- United States Department of the Interior. 1998. Pp 139-184 *in* Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment - Selenium. National Irrigation Water Quality Program Information Report No. 3.
- United States Fish and Wildlife Service. 1998. Recovery plan for upland species of the San Joaquin Valley, California. Region 1, Portland Oregon. 319pp.
- Uptain, C. 1995. Habitat recovery on the north kern prison site: A summary of six seasons of monitoring. Submitted to California Department of Corrections, Sacramento, California.
- van der Molen, W. H. 1976. Natural factors. In Prognosis of Salinity and Alkalinity, Soils Bulletin 31, Food and Agriculture Organization of the United Nations, Rome, Italy, pp.31-52.
- van Schilfgaarde, Jan. 1976. Water management and salinity. 1976. In Prognosis of Salinity and Alkalinity, Soils Bulletin 31, Food and Agriculture Organization of the United Nations, Rome, Italy, pp.53-67.
- Walters, C. J. and C. S. Holling. 1990. Large scale management experiments and learning by doing. Ecology 71:2060-2068.
- Wan, H. F., R. L. Mikkelsen and A. L. Page. 1988. Selenium uptake by some agricultural crops from Central California. J. Environ Qual. 17:269-272.
- Wilkins, D. H. 1993. California's changing climates and flora. Pp. 55-58 *In* J.C. Hickman (ed.) Jepson Manual Higher Plants of California, UC Berkeley Press, 1400 pp.
- Wu, L., J. Chen, K. Tanji and G. S. Banuelos. 1995. Distribution and biomagnification of selenium in a restored upland grassland contaminated by selenium from agricultural drain water. Environmental Toxicology and Chemistry 14(4):733-742.
- Wu, JunJie and Bruce A. Babcock. 1996. Contract Design for the Purchase of Environmental Goods from Agriculture. American Journal of Agricultural Economics 78(4):935-945.
- Wu, Q.J, Dun, S., and Kumar, A. 1998. Numerical simulation of ground-water flow and selenium transport in the western San Joaquin Valley, California.
- UC Salinity/Drainage Program Annual Report, Sacramento, California.
- Zahm, G. R. 1986. Kesterson Reservoir and Kesterson National Wildlife Refuge: history, current problems and management alternatives. Transaction of the North American Wildlife Natural Resource Conference 51:324-329.

Zawislanski, P. T., T. K. Tokunaga, S. M. Benson, J. M. Oldfather and T. N. Narasimhan. 1992. Bare soil evaporation and solute movement in selenium-contaminated soils of Kesterson Reservoir. *Journal of Environmental Quality* 21:447-457.

Zawislanski, P. T. and M. Zavarin. 1996. Nature and rates of selenium transformations: A laboratory study of Kesterson Reservoir soils. *Soil Science Society of America Journal* 60:791-800

APPENDIX [CVPIA SECTION]

Land Retirement Program - Interim Guidelines

**CENTRAL VALLEY PROJECT IMPROVEMENT ACT
SECTION 3408(h)**

**LAND RETIREMENT PROGRAM
INTERIM GUIDELINES**

NOVEMBER 1997

**United States Department of the Interior
Interagency Land Retirement Team
2666 North Grove Industrial Drive, Suite 106
Fresno, CA. 93727-1551**

**CENTRAL VALLEY PROJECT IMPROVEMENT ACT
SECTION 3408(h)
LAND RETIREMENT PROGRAM
INTERIM GUIDELINES**

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I. INTRODUCTION

On October 30, 1992, Congress enacted Public Law 102-575. Section 3408(h)(1), Title XXXIV of Public Law 102-575 (known as the Central Valley Project Improvement Act or CVPIA), authorized a federal land retirement program, as recommended in the San Joaquin Valley Drainage Program Final Report (SJVDP, Sept. 1990). Also in 1992, the California State Legislature passed Senate Bill 1669 (SB 1669), the San Joaquin Valley Drainage Relief Act that incorporated the SJVDP recommendations. This State statute authorized a land retirement program (California Water Code, Section 14900) to be administered through the California Department of Water Resources (DWR).

A comprehensive study of agricultural drainage and drainage-related problems on the Westside of the San Joaquin Valley resulted in the management plan presented in the San Joaquin Valley Drainage Program (SJVDP) final report issued in September 1990. The recommended drainage management actions included the selective retirement of irrigated lands that are characterized by low productivity, poor drainage, and high selenium concentrations in shallow ground water. As currently envisioned, this Land Retirement program will be accomplished cooperatively by the Department of Interior (BOR, FWS, BLM) and California's Department of Water Resources (DWR) through a process in which willing sellers volunteer to remove their lands from irrigated production in return for compensation.

Land retirement, or taking lands out of irrigated agricultural production, is a way to reduce irrigation drainage problems. Since irrigation water is no longer applied there would be reductions in the amount of subsurface drainage water produced. With less water moving through the soil profile, less leaching would occur, thereby reducing the amount of salts and other solids passing into the drain water. Other associated benefits would be the lowering of the water table, and opportunities to use the Project water, which was previously used on the retired lands, on other lands and to increase or enhance fish and wildlife resources, by changing the land use.

Public meetings were held in December 1993 and two 'Involved Parties' meetings were held in winter and spring 1994. In addition, presentations, and input and discussion meetings, were held with specific constituent groups such as the San Luis Delta-Mendota water users, San Joaquin Valley Drainage Implementation Program Management Group, Drainage Oversight Committee, and others. Draft interim guidelines were mailed to the involved parties list in early May, 1994. Few substantive comments resulted from this review of the preliminary draft

II. OBJECTIVE

The objective of these Interim Procedures and Guidelines is to establish the process and selection criteria for the acquisition, from willing participants, of land and associated water rights, as authorized in Section 3408(h) CVPIA and Section 14900 CWC. This process is referred to as the Land Retirement program.

Both the State and Federal land retirement authorizations are based, in part, upon recommendations of the San Joaquin Valley Drainage Program. Therefore, in consideration of the similar objectives of the State and Federal statutes, the Department of the Interior and the State Department of Water Resources have agreed in concept to undertake a Joint Federal-State land retirement program. Such a joint program would avoid duplication and confusion, increase efficiency of both efforts, and maximize flexibility and versatility of the program.

Generally, a single pool of prospective applications would be evaluated, priorities set and both Federal and State resources then utilized, as available, to effect the greatest net benefit to the overall program objectives. Therefore, these Interim Guidelines are designed to accommodate implementation of this joint program, covering both the Federal and State authorizing statutes, where practicable.

III. AUTHORITY

CENTRAL VALLEY PROJECT IMPROVEMENT ACT, PL 102-575,
TITLE XXXIV

Section 3408(h)(1) authorizes the purchase, from willing sellers, of land and associated water rights and other property interests identified in paragraph (h)(2) which receives Central Valley Project water under a contract executed with the United States, and to target such purchases to areas deemed most beneficial to the overall purchase program, including the purposes of this title.

Section 3408 (h)(2) authorizes the Secretary to purchase, pursuant to such rules and regulations as may be adopted or promulgated to implement the provisions of this subsection, agricultural land which, in the opinion of the Secretary -

- A. would, if permanently retired from irrigation, improve water conservation by a district, or improve the quality of an irrigation district's agricultural wastewater and assist the district in implementing the provisions of a water conservation plan approved under section 210 of the Reclamation Reform Act of 1982 and agricultural wastewater management activities
- B. developed pursuant to recommendations specific to water conservation,

drainage source reduction, and land retirement contained in the final report of the San Joaquin Valley Drainage Program (September 1990);

OR

- B. are no longer suitable for sustained agricultural production because of permanent damage resulting from severe drainage or agricultural wastewater management problems, groundwater withdrawals, or other causes.

SAN JOAQUIN VALLEY DRAINAGE RELIEF ACT, California Water Code (CWC), Section 14900

The State program as authorized by and described in CWC, Sect.14900, is to encourage cessation of irrigation on drainage-impaired lands and assist in the resolution of agricultural subsurface drainage problems in the San Joaquin Valley through the coordinated efforts of Federal, State and Local agencies, Non-profit organizations, and private landowners who elect to participate in the program.

Basic program elements. are:

The Department of Water Resources may acquire and manage drainage-impaired land, and acquire and transfer associated water.

The area of focus is the 75,000 acres referenced in the final report of the San Joaquin Valley Drainage Program (SJVDP), but could be anywhere in California.

The program must be self-supporting through the sale of conserved water.

The land acquired would be managed as habitat or non-irrigated agriculture.

One-third of the water conserved but not sold may be used by local agencies for environmental purposes or ground water recharge.

Distribution of conserved water must maximize amounts for environmental purposes.

IV. APPLICABILITY

These Interim Guidelines will be effective immediately and apply to the implementation of an interim program to retire irrigated agricultural lands which receive Central Valley Project water under a contract with the United States. This interim program pursuant to these Interim Guidelines will remain in effect until final rules and regulations for PL 102-575 are promulgated. However, as the interim land retirement program proceeds, these Interim Guidelines may be revised as necessary.

The applicability of these Interim Guidelines will not impede or restrict in any manner the execution of any land/and or water transaction between or among the United States, the State of California, or any person or entity.

V. PURPOSE

The purposes of the land retirement program are:

- A. Assist water districts in implementation of an approved water conservation plan, or improve the quality of an irrigation district's agricultural wastewater through drainage source reduction.
- B. Acquire water for purposes identified in the Central Valley Project Improvement Act and/or the San Joaquin Valley Drainage Relief Act.
- C. Protect, restore, and/or enhance fish and wildlife resources.

VI. ELIGIBILITY

GEOGRAPHIC AREA

Lands eligible for participation in this interim land retirement program are those that:

Receive Central Valley Project water under a contract executed with the United States (for participation under the Federal program)

OR

Are located in the drainage problem study area as defined in the final report of the San Joaquin Valley Drainage Program September, 1990. (for participation under the State program)

OFFERS

Offers will be considered from any and all landowners, groups of landowners, their duly authorized representatives and any combination thereof.

Offers involving multi-party arrangements must include all necessary parties legally capable of executing the terms of the offer.

TYPES OF TRANSACTIONS

Any and all types of transaction possibilities will be considered (fee acquisition, lease, lease- purchase, easement, etc.), provided the transaction meets the requirements for land retirement as specified in the Act.

VII. PROCESS

OVERVIEW

The program will be on a willing seller basis. Offers will be solicited by the land retirement team from willing sellers within the eligible area as described in section VI. A two-part process will be used to evaluate and select lands to be included in the interim land retirement program. Interested participants will be asked to submit an initial application form outlining the terms and conditions of the offer, and basic information needed to screen offers for eligibility and potential to meet goals of the program. The preliminary application will be as short and non-burdensome as possible, and require only basic information likely to be known or readily available to the landowner. The second part of the process will require more detailed information, and will be developed only for lands which might reasonably be considered.

A. Solicitation of Offers

A proactive effort to retire those lands which meet the priorities of the program and the objectives of the Act will be an ongoing process throughout the life of the program. Offers will be solicited by the land retirement team on a recurring basis, generally annually. An announcement will be made following determination of the currently available Federal and State funds for the land retirement program. The announcement will identify the period covered by the announcement, general land retirement program goals, the selection criteria, and instructions for those who wish to submit offers. Announcements will be mailed to landowners, local and State government agencies, and persons that have requested to be kept informed through general mail. The

announcement will also be published through advertisements taken in newsletters through Farm Bureau, Water Districts, Drainage Districts, and/or through public newspapers. Applications will be accepted for a period of 60 days from the date of publication of the solicitation announcement. Applications received after this date will be considered in the next round.

B. Applications

Preliminary Application

Those interested in participating in the program will submit a non-binding application responsive to the criteria. The purpose of the preliminary application will be to 1) express interest in participating in the program, 2) identify under what terms and conditions the interest is based, and 3) provide sufficient information for a determination of eligibility and initial evaluation of the offer with respect to goals and objectives of the program.

Attachment 1 shows the minimum information that will be requested in the preliminary application phase. Return completed applications to Land Retirement Program Manager, USBR South-Central California Area Office, 2666 N. Grove Industrial Dr., Suite #106, Fresno, CA 93727.

C. Review

A review committee will be established consisting of State and Federal agency personnel with technical expertise and experience relative to the selection criteria. Upon the closing date for applications, this group will review the applications for eligibility and priority according to their potential to meet the purposes of the program. Applicants will be notified of the status of their application within 60 days of the closing date.

D. Preliminary Selection

Applications, once determined to meet the minimum eligibility criteria described above, will be evaluated and prioritized according to pre-determined criteria. Data and information utilized for evaluation will be provided by the applicant, and through State, Federal, or Water District data bases. The Selection Criteria Matrix is contained in the Appendix.

E. Confidentiality

Information about a particular transaction or potential transaction, including information about property owners involved and lands being considered for retirement, will be held in confidence by agency personnel (Federal and State) until negotiations about that particular transaction

have been completed and a letter of intent has been signed. Information about applications that are not selected, potential transactions that do not progress to formal negotiations, and other discussions will also be held in confidence.

F. Notification

Applicants will be notified within 60 days of the close of the application period of the status of their applications. A supplemental information packet will be sent to those who have been selected to participate in the final process. This packet will contain instructions, requests for specific additional information, and a time line with mandatory response dates.

G. Final Review and Selection

Based upon the supplemental information packet provided by the landowner and upon the guidelines and purposes of the land retirement program, an assessment of the applications will be made and recommendations for selections will be made by the review committee and forwarded to management for approval. Upon approval, those selected parcel owners will be notified, and formal negotiations will be initiated. Qualified applicants who are not selected for participation in this round will automatically be placed on the list to be considered for the next solicitation event (unless the applicant requests otherwise).

VIII. RETIREMENT OF LAND

- A. Land to be retired under the Federal program shall be appraised by a Department of the Interior appointed appraiser, and shall include a hazardous materials inspection, according to the standards for such inspections set by the American Society for Testing and Materials, E-1527-97 & E-1528-96. Lands to be retired under the State program will follow a similar process.
- B. Lands found to contain hazardous wastes¹ are not eligible for lease or acquisition, unless the identified hazardous materials are removed and certified prior to public agency lease or purchase.
- C. All debt service against the land to be retired, shall be retired prior to, or as part of, any fee purchase agreement or included as part of the lease arrangements.

¹1. Environmental Protection Agency's publication entitled *National Priorities List Fact Book* (December 1992) and supplements, which identify hazardous waste sites requiring cleanup under the "Superfund" law.

- D. Appropriate environmental review and documentation shall be prepared and completed prior to transaction closure.
- E. A post retirement land management plan shall be developed by the management agency or entity prior to retirement of a parcel of land. The post-retirement plan shall include, as necessary, consultation, coordination and review by other agencies and interested parties to ensure any potential adverse effects of post-retirement management are addressed.

IX. WATER MANAGEMENT

- A. All irrigation activities will cease, except for limited land management purposes which will not contribute to existing drainage problems.
- B. Water from retired land will not be used where it may contribute to existing agricultural drainage pollution problems, or other shallow groundwater related problems.
- C. Water acquired for fish and wildlife, or other purposes of this Act, through the interim land retirement program may be transferred for future use(s) on lands outside the District in which the acquired land is located in accordance with CVPIA sections 3406(b)(3), water acquisitions and 3405(a), water transfers.

X. DEFINITIONS

As used herein, the term:

“Act”

means Title XXXIV of Public Law 102-575, known as the “Central Valley Project Improvement Act” or CVPIA.

“Agricultural Land”

means those lands which are utilized to grow a marketable crop of botanical or biological nature, and are not used for Municipal or Industrial use.

“Drainage water”

Surplus water removed from within the soil by natural or artificial means, such as by drains placed below the surface to lower the water table below the root zone.

“Easement”

means an interest in land owned by another that entitles its holder to a specific limited use

“Fee acquisition”

means purchase of land in complete title with the associated rights.

“Interim Program”

means the time period between the initiation of the land retirement program and that time when the PEIS has been accomplished and final rules and regulations have been promulgated.

“Irrigation Water”

means Project Water to be used for agricultural purposes as set forth in the Water Contractor’s Water Service, Repayment or Water Right Settlement Contract.

“Land Retirement”

means cessation of irrigation upon a parcel of land.

“Lease”

Negotiated contract granting use of the land for a specified period and for a specified amount.

“Lease-purchase”

means a negotiated contract granting use of the land for a specified period and for a specified amount, which includes an option to purchase (fee title) in a given time period.

“Multi-party” arrangement

refers to land acquisition/lease proposals with more than one landowner of record, such as a partnership, deeds held in Trust, etc...All legal owners (those legally capable of executing the terms of the offer) must sign the offer.

“Municipal and Industrial Water”

means Project Water to be used for other than agricultural purposes as set forth in the Water Contractor’s Water Service, Repayment or Water Rights Settlement Contract.

“Project”

means the Central Valley Project, California

“Project Water”

means water that is developed, diverted, stored or delivered by the Secretary in accordance with the statutes authorizing the Central Valley Project and in accordance with the terms and conditions of water rights acquired for the Central Valley Project pursuant to California law.

“San Joaquin Valley Final Report” (SJVDP final report)

means the final report of the San Joaquin Valley Drainage Program dated September 1990. (a.k.a. the “rainbow report”).

“Secretary”

means the Secretary of the Interior, or his designee.

“Wastewater”

refers to agricultural drainage wastewater, commonly collected in subsurface collector drains in shallow water tables and transported via ditches and canals to evaporation ponds or streams.

“Water Conservation Plan” (WCP)

refers to the water conservation plan as developed in accordance with provisions of the Reclamation Reform Act (RRA) and CVPIA by the CVP water contracting district in which that parcel is located.

“Water Contractor”

shall mean any entity or individual who is a party to a Water Service Contract, a Repayment Contract or a Water Rights Settlement Contract with the United States for a Project Irrigation and/or Municipal and Industrial Water supply, which may be supplemental to a non-Project water supply, pursuant to Section 9 of the Reclamation Project Act of 1939, as amended and supplemented.

“Water Districts”

refers to water contractors.

Water Service Contract”

means a contract with the United States providing Project Water pursuant to subsections (c)(2) and/or (e) of Section 9 of the Reclamation Project Act of 1939, including Water Rights Settlement Contracts which provide for the delivery of supplemental Project Water.

XI. APPENDIX

**CVPIA LAND RETIREMENT PROGRAM
PRELIMINARY APPLICATION**

(A SEPARATE APPLICATION MUST BE FILLED OUT FOR EACH PARCEL OR BLOCK OF LAND)
Purpose of Retirement (eligibility for): Water Conservation (), Drainage (), Other ()

1. Owners Name _____ Phone # () - _____
Address _____, City _____, St. _____, Zip _____

2. Location of Acreage : APN # _____
Address _____
County _____ Township _____ Range _____ Section _____ Meridian _____
Attach Parcel map to this form.

3. Total Asking Price \$ _____, Per Acre \$ _____
water allocation included? (yes / no)
Terms: _____

(use reverse-side for additional space)

4. Number of Acres _____ **5. Water District** _____
6. Water Allocation _____ ACRE FEET total _____, or per acre _____
explain: _____

7. Crop History: (identify crop and production, dry pasture or fallow for past 10 years)

Year 1 Crops	_____	Production per Acre	_____
Year 2 Crops	_____	Production per Acre	_____
Year 3 Crops	_____	Production per Acre	_____
Year 4 Crops	_____	Production per Acre	_____
Year 5 Crops	_____	Production per Acre	_____
Year 6 Crops	_____	Production per Acre	_____
Year 7 Crops	_____	Production per Acre	_____
Year 8 Crops	_____	Production per Acre	_____
Year 9 Crops	_____	Production per Acre	_____
Year 10 Crops	_____	Production per Acre	_____

Has parcel been idled more than 4 years? (yes/no)

8. Drainage History:

Method of Irrigation (circle all that apply) Sprinkler Flood Furrow
Drip Comb.
Wells on Property? (yes / no), Depth of Wells _____ Depth to useable water _____
Collector drains? (yes / no), Depth to shallow ground water _____

9. Please note any other features that may add value on the back of this application

(e.g. House, Barns, Outbuildings, Wildlife / Wetland Compatibility, Cost savings of drainage cleanup, etc.)

Signature: _____ **Date:** ____ / ____ / ____

Return this form to: Land Retirement Program Manager, USBR SCCAO,
2666 North Grove Industrial Dr., #106, Fresno, CA 93727

Does parcel receive CVP water?	Y	N
Drainage Reduction	Max Pts:	Score
Depth to Groundwater		
0-5 ft.		
5-10 ft.		
>10 ft.		
Selenium		
> 200 ppb		
50-200 ppb		
20-50 ppb		
5-20 ppb		
Salinity(e.c.)		
>10 dS/m		
5-10 dS/m		
2.5-5 dS/m		
>0-2.5 dS/m		
Boron		
> 8ppm		
2-8 ppm		
0-2 ppm		
Soil Drainage Class		
Poorly Drained		
Moderately Drained		
Well Drained		
Other		
As > 10 ppb		
Mo > 10 ppb		
Totals for Drainage Reduction:		

Fish & Wildlife		
Max pts: _____ Score: _____		
Risk of Exposure to contaminated waters		
Active drain to SJR/pond		
Potential drain to SJR/pond		
No drains		
Parcel Size		
Parcel size		
Parcel location		
Parcel is within 1 mile of managed habitat		
Parcel is between 1-5 miles of managed habitat		
Parcel is located contiguous to river or perennial stream, or within its historical floodplain		
Retirement of parcel will assist in implementation of current habitat management/recovery/conservation plans (corridor concept)		
Geographic relationship of parcel to other parcels in applicant pool		
Parcel is >5 miles from urban development or high-use facilities		
Totals for Fish & Wildlife Enhancement:		

Acquisition of Water for CVPIA Purposes		
Max pts: _____ Score: _____		
Entire water district (assignment of water contract)		
Amount of water available for acquisition		
Totals for Acquisition of Water:		

TOTALS	
Maximum possible points	
Applicant's score	

Instructions for using Ranking Criteria

Does Parcel Receive CVP water? (Y/N) This is to document eligibility of parcel for the land retirement program, per requirements of sect. 3408(h), CVPIA.

Drainage Reduction

Depth to Groundwater taken from San Joaquin Valley Drainage Program Final Report, 1990 dataset, or most current GIS data

Selenium--same

Salinity--same

Boron--same

Soil Drainage Class--obtained from NRCS.

Other--As, Mo obtained from GIS dataset listed above

Fish & Wildlife

Risk of Exposure to contaminated waters: in order to factor in the risk of contaminant exposure to wildlife from such things as selenium, arsenic, etc., we need to know the pathway of the drainage and irrigation tailwater and the ultimate destination of these waters.

Parcel Size: simply multiply the acres available by 0.01, capped at 50 pts.

Parcel Location

Parcel within 1 mile of managed habitat: managed habitat is defined as lands in public ownership or a private preserve, managed for native species

Parcel is between 1-5 miles: using definition of managed habitat, use GIS map to locate proximity of parcel to other managed habitat.

Parcel is located contiguous to river or perennial stream, or within its historical floodplain: using GIS dataset and floodplain maps, determine location of parcel relative to this criterion. Criterion is important because riparian habitat is rare.

Retirement of parcel will assist in implementation of current habitat management/recovery/conservation plans (linkage concept): flexibility is needed here to obtain parcels that are key linkages to complement other program efforts. Determination of parcel importance includes such things as threatened and endangered species, and other wildlife values.

Geographic relationship of parcel to other parcels in applicant pool: Using GIS map, compare location of offered parcel to other parcels in the applicant pool, previously selected lands, managed public lands, etc. to form “linkages”, and larger block sizes.

Parcel is >5 miles from urban development or high-use facilities: Urban development is defined as areas with populations of 20,000 or more. High-use facilities are defined as those that have created major land disturbance activities and are operated on a daily or continual basis. Major land disturbance activities may include borrow pits, sand and gravel operations, airports, freeway interchanges, etc.

Acquisition of Water for CVPIA Purposes:

Entire water district (assignment of contract)--if able to purchase the entire water district, the purchaser assumes control of the water contract and can easily move water elsewhere, such as to refuges, in accordance with CVPIA, section 3405(a)(1) and (2) water transfers. Assumption of the contract is of great benefit as it locks up a stable supply of water (no allocation uncertainties), may reduce long-term operation and maintenance costs and debt-load issues, which may improve water management and conservation in accordance with CVPIA, section 3405, Water Transfers, Improved Water Management and Conservation.

Amount of water available for acquisition: - multiply acre-feet offered by 0.01 per acre-foot.

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